# **Sub-Basin Conditions**



#### CHAPTER 4

#### SUB-BASIN CONDITIONS

منبو

#### SECTION 4.1 INTRODUCTION

The planning area contains six sub-basins. Each exhibits different natural characteristics with respect to the mix of geology, soils, and habitat. Consequently, when exposed to the varying land use and storm flow patterns, important differences emerge that must be considered in determining effective solutions for that sub-basin. This chapter contains interdisciplinary analyses of conditions for each of the sub-basins in the planning area: West Branch Hylebos Creek (4.2), East Branch Hylebos Creek (4.3), Lower Hylebos Creek (4.4), and Lower Puget Sound (4.5), which includes discussions of the North, Central, and South Lower Puget Sound sub-basins. Disciplinary perspectives included in these analyses are geology, drainage and flooding, habitat, and water quality.

# SECTION 4.2 WEST BRANCH HYLEBOS CREEK

#### INTRODUCTION

The West Branch Hylebos Creek sub-basin contains some of the best remaining habitat in the Hylebos Creek and Lower Puget Sound basins, the West Hylebos Wetland a significant resource county-wide, and important recharge areas for the Federal Way groundwater supplies. This sub-basin also has the highest land-use density in the Hylebos Creek and Lower Puget Sound basins, which has resulted in significant flooding, instream erosion, nonpoint source pollution, and a much degraded fishery resource.

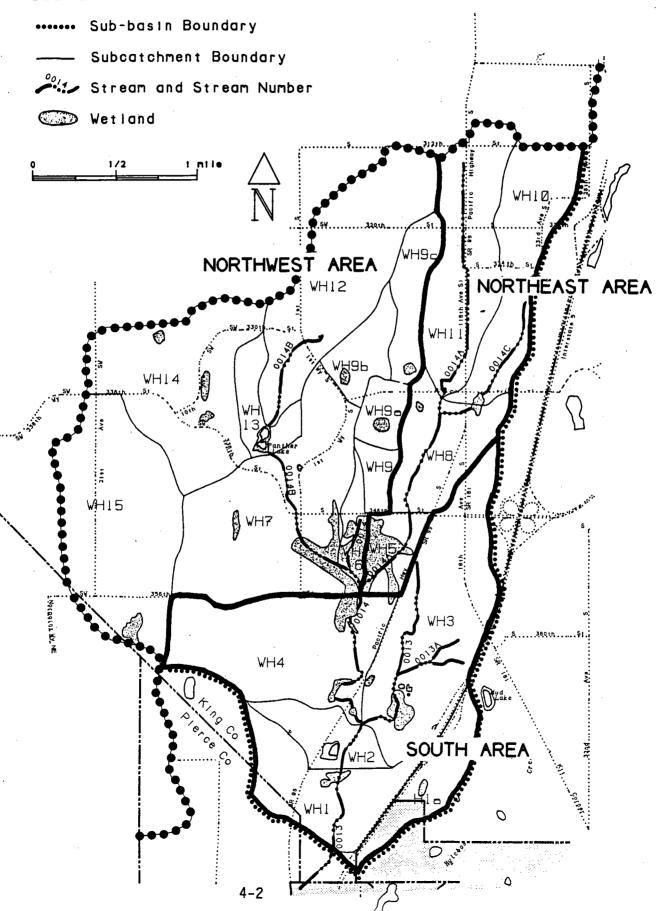
#### SUB-BASIN DESCRIPTION

The West Branch Hylebos Creek sub-basin consists of approximately 4300 acres tributary to 9.7 miles of stream channel (Figure 4.2.1). Geology in the upper reaches is primarily composed of till deposits with scattered overlying recessional outwash with a mainly subsurface tongue of advance outwash known as the Milton-Redondo Channel trending southeast from Puget Sound. The headwaters of the sub-basin have been heavily altered by urbanization with commercial, business park, and multifamily developments and a network of roads that generate the bulk of nonpoint source pollutants in the basin. Three major tributaries, 0014, 0014A, and 0014B, discharge from this urban area and converge within the West Hylebos Wetland. Because of high storm flows, high nonpoint source pollutant concentrations, and low summer base flows, aquatic habitat is limited or nonexistent in the northern half of the sub-basin.

The land use south of the West Hylebos Wetland contrasts substantially with that north of the Wetland. Overall development densities are much less than the north area with large tracts of undisturbed forest in many areas. The stream channels have been altered to a lesser degree, although several stretches of tributary 0014 have been encroached upon and the upper reaches of the north fork of the West Branch (tributary 0013) have been piped. Despite the lower den-

# West Branch Hylebos Creek

SUB-BASIN MAP



sities, streams in the southern half of the sub-basin continue to be severely impacted by the cumulative effects of high flows, pollutants, and sediments transported from the northern half of the sub-basin. Aquatic habitat in the West Branch currently exists between Brook Lake in the West Hylebos Wetland and the confluence of tributary 0013 with the East Branch Hylebos Creek, and in tributary 0013 south of S 359th Street. Historical accounts indicate that the Hylebos Creek system may have been one of the most productive small stream systems in central Puget Sound, supporting large numbers and a wide diversity of anadromous and resident species. Currently, the West Branch supports mainly chum salmon, sustained largely by out-planting, and cutthroat trout.

# **CONDITIONS**

#### Current

To facilitate this discussion, the West Branch Hylebos Creek sub-basin was divided into three areas: the Northeast, Northwest, and South. The Northeast area consists of tributaries 0014A and 0014C, and includes the heavily urbanized area along S 320th Street and part of the West Campus Office Park. The Northwest area consists of the area tributary to 0014B and tributary 0014 north of S 356th Street. This area includes Panther Lake and an area of high infiltration northwest of Panther Lake. The South area includes the rest of the basin south of S 356th Street. This area is lower in existing development density than the north sub-basins and contains the majority of the viable fish habitat. The following sections describe the conditions of the West Branch under current land-use conditions.

Northeast Tributary Area - The northeast tributary area is the most densely developed in the planning area. This portion of the sub-basin has 40 percent impervious surface compared to 19 percent for the entire West Hylebos sub-basin. The streams within this area receive runoff from the commercial uses along S 320th Street, which include the Sea Tac Mall and SR 99. Runoff from the commercial corridor along S 320th Street (subcatchments WH10 and WH11) has resulted in nearly a tripling of peak flow runoff over predeveloped conditions despite onsite detention controls (see Figure 4.2.2). Wetlands located at the southeast and southwest corners of S 336th Street currently attenuate these flows; however, filling and encroachment has reduced the flow and pollutant buffering capacity.

SR 99 occupies what historically was the stream channel of tributary 0014A north of S 336th Street. Runoff from SR 99 and the adjacent commercial areas is conveyed downstream via a culvert system beneath the highway. Flow and pollutant reduction is therefore minimal along this reach of stream. Flows from tributary 0014A constitute over 85% of the storm flows entering the West Hylebos Wetland. Stream damage from high flows is most severe along tributary 0014A downstream of S 336th Street with severe channel incision interspersed with local zones of gravel deposition. High metal and fecal bacteria concentrations were measured in Tributary 0014A at S 336th Street (see Figure 4.2.3). During storm events, water at this site was noted as cream colored and carried a significant oil/grease sheen.

Existing onsite detention ponds in the east tributary area provide negligible detention compared to what is actually needed to reduce flows and pollutants to non-damaging levels. Many sites were developed prior to King County detention

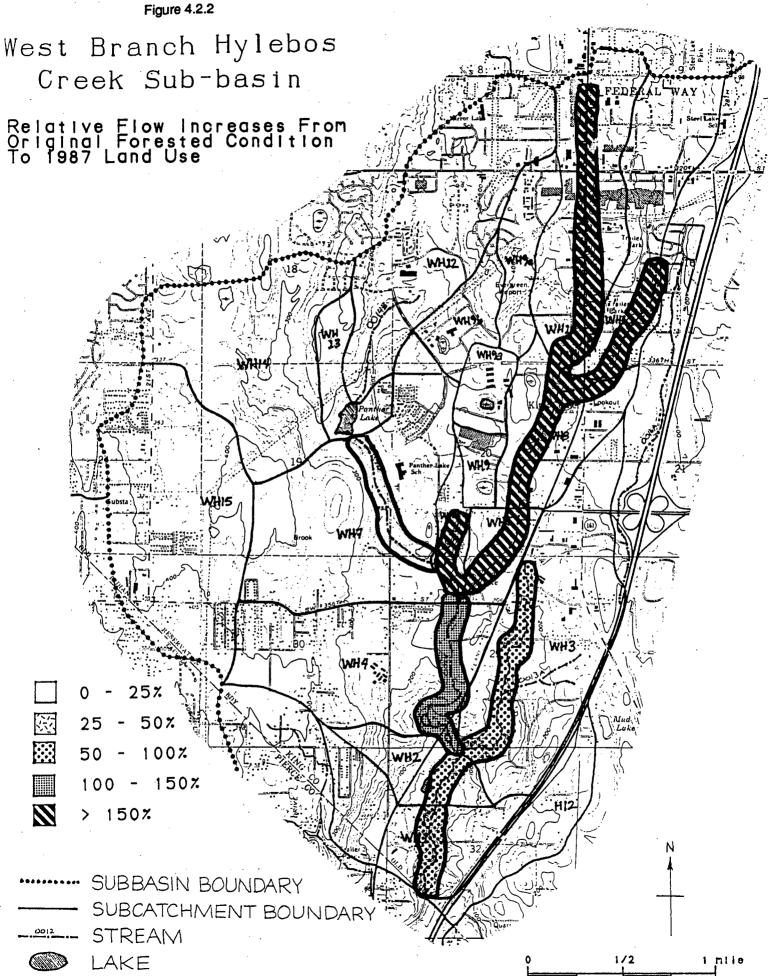


Figure 4.2.3

# West Branch Hylebos Creek

COMPOSITE EXISTING CONDITIONS MAP Adversely Affected Areas Flooding Erosion and Sedimentation Habltat Water Quality Significant Resource Area Needing Protection : lood Storage WHI4 **V**H15 Sub-basin Boundary Subcatchment Boundary Stream and Stream Number Wetland.

ordinances. Several of the developments along S 320th Street including the Sea-Tac mall have on-site detention ponds, however, many appear to be too small, or designed with too large of a release rate, so that the majority of storm flows are not detained. The detention pond at Sea-Tac Mall near the headwaters of tributary 0014C appears to have sufficient volume to attenuate flows from even large storms, however, the outlet pipe is so large that only four out of fifteen feet of pond storage were actually used during the 50-yea. January 1990 storm.

1

٠,

King County has identified three potential sites for regional detention to reduce flows entering the West Hylebos Wetland, reduce flooding on S 336th Street, reduce flooding along SR 99 south of S 336th Street, and improve water quality. These projects are located in the wetlands on tributaries 0014A and 0014C at S 336th Street. Filter berms and biofiltration will be included in the project designs to reduce pollutant loadings to the downstream system including the West Hylebos Wetland.

Northwest Tributary Area - Flows entering the West Hylebos Wetland from tributary 0014 are remarkably small, considering that the tributary area is heavily developed at multifamily and commercial densities. The majority of this development is contained within the West Campus Master Planned Development, which has retention/detention ponds that currently reduce storm peak flows. These ponds are located in highly permeable soils and infiltrate much of the runoff discharging to them.

The Panther Lake tributary-area (subcatchments WH15, WH14, WH13, and WH12) has historically been a closed depression. Surface runoff from the surrounding, relatively impervious till areas in the uplands of subcatchment WH12 was infiltrated into Panther Lake and its surrounding pervious outwash deposits. In the late 1970s, the West Campus Master Planned Development began using Panther Lake as a stormwater detention facility and installed an outlet pipe to carry flows above a 25-year recurrence interval to tributary 0014B. Subcatchment WH15, upstream of Panther Lake, also was a closed depression historically, infiltrating surface runoff into a depressional wetland formerly located at the northern end of the subcatchment. The filling of and subsequent construction on this wetland has resulted in the addition of 480 acres of tributary area to Panther Lake. The additional tributary area, compounded by urbanization and sedimentation of the bottom of Panther Lake from development, has resulted in Panther Lake discharging surface runoff at a 20-year recurrence interval under 1987 land use. This recurrence may have been further reduced in the past few years because of increased sediment loading to Panther Lake.

Sediment transport downstream of Panther Lake in tributary 0014B had been limited in the past because of the infrequent discharge from the Lake. Low gradients along that channel probably will limit the amount of future incision that will occur, but active transport of fine sediment into the West Hylebos Wetland will likely increase with the higher, more frequent discharge from Panther Lake. Expansion of that channel with increased flows already appears to be occurring.

The West Hylebos Wetland is the largest in the Hylebos Creek and Lower Puget Sound basins and represents a significant regional resource. Located at the confluence of tributaries 0014, 0014A, and 0014B, it is sustained by unique physiographic, hydrologic, and habitat conditions which have been affected by urbanization. Increased winter storm flows, especially from tributary 0014A, have deposited silt and pollutants and increased the duration of inundation,

thus adversely affecting some plant species in the wetland. Development and loss of recharge areas in the Panther Lake tributary area, and perhaps the long-term pumping of groundwater from deeper aquifers, may threaten the groundwater supplies that currently sustain the wetland through the summer.

South Tributary Area - Land use south of the West Hylebos Wetland is markedly less dense than to the north, with the contribution of flows, pollutants and sediment being similarly less. However, high runoff rates from the northern part of the sub-basin have resulted in significant damage and flooding to the lower stream system. Riparian vegetation has been reduced by grazing and bank trampling from RM 1.00 to 1.20, by channelization and dredging from RM 1.20 to 1.30, and by bank armoring for flood control at RM 0.24 to 0.44 on tributary 0014.

High flows from the north, combined with loss of riparian corridors and several channelized reaches, has resulted in reduced use of much of the lower mainstem by salmonids. One notable exception is the north fork of the West Branch Hylebos Creek (0013) in subcatchment WH3. This subcatchment contains a relatively wide, undisturbed riparian corridor between I-5 and SR 99 south of S 359th Street. The upper reaches of the subcatchment (north of S 359th Street) is currently developed at commercial densities; however, the diversion of 604 acres of the upper basin into the East Branch Hylebos Creek in the mid 1960s, and an extensive riparian wetland system have helped mitigate the increased peak flow runoff. This reach currently represents the only remaining portion of the Hylebos stream system containing both spawning and rearing habitat, although it is under-utilized. One reason for low fish counts may be poor water quality (e.g., metals and solids) from the urban area in the headwaters (Figure 4.2.3). Limited implementation of Best Management Practices (BMPs) associated with this urban area have resulted in the highest concentrations of pollutant loading to the West Branch Hylebos sub-basin. Excellent riparian vegetation and good rearing habitat also exist in 0013 from RM 0.44 to RM 0.85 in the broad, forested riparian corridor behind Gethsemene Cemetary.

Low channel gradients and high flows have contributed to flooding at several locations in the recent past. One notable example is located near the S 373rd Street crossing of tributary 0013. The stream channel is located in a broad floodplain in which significant amounts of sediment are deposited during high flows. The sediment fills the channelized sections of stream, reducing flow capacity and have caused flooding of one streamside residence and the S 373rd Street bridge. High flows have also caused periodic closure of S 356th Street. High flows, in conjunction with channelization and floodplain encroachment at RM 0.30 on tributary 0014, have also caused instream erosion and flooding at the Montesorri School.

Severe sedimentation from peak flows during the December 5, 1989 and January 9, 1990 storms occurred within former spawning habitat from RM 1.10 to 1.30 in tributary 0013, burying chum and chinook salmon eggs that had been laid in this reach earlier in the fall. In the past spawning habitat within this same reach has been disturbed by channelization and periodic dredging to remove sediment deposited during storms. Spawning and rearing habitat in 0013 from RM 1.80 to 2.30 was also damaged, though to a lesser extent, due to sedimentation and scouring during the January 9, 1990 storm due to the washout of the road fill under S 359th Street. Stream bank armoring for flood control has eliminated most of the spawning and rearing habitat in tributary 0014 from RM 0.19 to 0.25. Further upstream from RM 0.57 to 0.71, erosive flows have replaced former

spawning gravels with unsuitably large cobbles and reducing rearing habitat in pools.

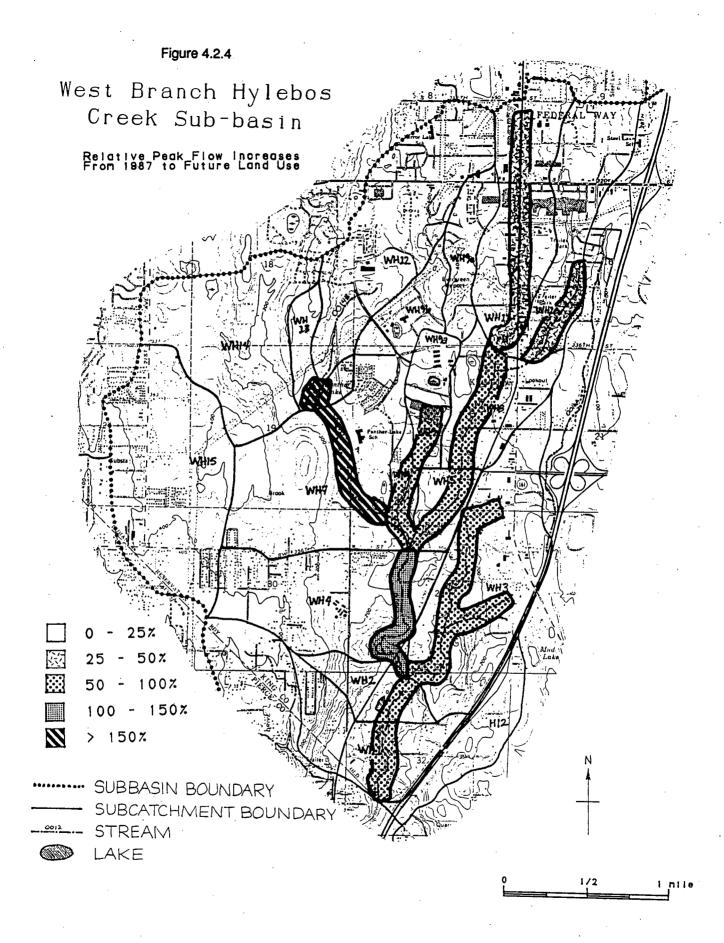
#### **Future Conditions**

Land use under build-out conditions in the West Hylebos sub-basin is the most intense in the study area. The majority of the north half of the sub-basin is designated to be developed at multifamily, business park, and commercial densities. The southern half is zoned for high-density single family, with some rural zoning in the extreme south. Increased damage with urbanization could be dramatic in the West Hylebos sub-basin, because roughly 50 percent of the subbasin still remains forested under 1987 land use. Flows at the outlet of the West Hylebos Creek basin are predicted to nearly double, with increases of greater than 150 percent expected from the Panther Lake subcatchment (tributary 0014B) (Figure 4.2.4). Elsewhere in the basin, flow increases in the range of 50 to 100 percent over 1987 land use predominate. If adequate surface water controls are not in place to mitigate increased runoff and nonpoint source pollution, the frequency and magnitude of existing flooding will increase, areas that historically did not flood will begin to do so, and the already imperiled fishery resource will simply cease to exist. The following sections discuss the area-specific effects of future land use on the West Branch Hylebos Creek subbasin.

Northeast Tributary Area - Peak flow increases in the headwaters of tributary 0014A are predicted to be the smallest, because the upper basin is already developed at commercial densities. South of S 336th Street, however, conversion of undeveloped and low-density land to commercial and office park densities may increase flows in 0014A by 50 percent. Existing erosion in this reach between S 348th and S 336th Streets will likely worsen, to the detriment of the West Hylebos Wetland located downstream.

Northwest Tributary Area - Loss of infiltration areas in the Panther Lake drainage is predicted to increase the magnitude and frequency of discharge from Panther Lake. Under future land use, Panther Lake is predicted to release surface flows at more than an annual occurrence, with a flow of 78 cfs at the annual recurrence interval. Under 1987 conditions, in contrast, it discharged only at about once in a 20-year frequency and was otherwise devoid of any discharge and a maximum runoff event from the 39-year model simulation of 170 cfs. Pollutant loading (e.g. fertilizer from lawns, oils, and heavy metals) associated with these higher flows will be greatly increased and may significantly impact salmonid spawning and rearing downstream. Increased erosion in tributary 0014B between Panther Lake and the West Hylebos Wetland, and the subsequent deposition of sediment in the wetland, will occur as the stream channel adjusts to the higher flow regime. In addition, aging septic systems and sewer lines over the next decade may increase fecal coliform loadings.

South Tributary Area - Flows in tributary 0014 downstream of the West Hylebos Wetland are predicted to increase by 125 percent under the future land-use scenario assuming no mitigation. Flow increases will aggravate existing erosion problems through a channelized section on tributary 0014 upstream of SR 99 at the Montesorri School. Flooding of S 356th Street will increase from a 10-year recurrence interval currently to less than a 2-year event under future conditions, and flooding at S 373rd will increase from a 100-year recurrence inter-



val to only a 5-year event. High flows during storm events, instream erosion and sedimentation, and the reduction of base flows will continue to degrade the already damaged stream habitat downstream of S 356th Street on tributary 0014.

The conversion of forested vegetation to high-density single-family residences in the north fork of West Branch Hylebos Creek (tributary 0013) is predicted to increase flows by 75 percent over 1987 land use. This subcatchment also contains 104 acres of wetlands not currently inventoried. These wetlands provide significant base flow in summer through groundwater discharge.

Without future detention, the remaining spawning habitat in tributary 0013 from RM 1.10 to 1.30 will continue to undergo massive periodic sedimentation during major storms. Habitat is expected to stabilize by installation of additional detention above S 359th Street. Placement of a 72-inch culvert under the road should also open usable fish habitat upstream. Future flooding could necessitate additional bank armoring for flood control in 0014 from RM 0.24 to 0.44, and possibly in reaches immediately upstream and downstream, rendering this stream segment virtually unusable by fish for either spawning or rearing. Deposition of sediment from upstream sources could also damage the existing high quality rearing habitat in 0013 from RM 0.80 to 1.10.

#### **KEY FINDINGS**

- West Branch Hylebos Creek has the most dense land-use zoning of any sub-basin in the Hylebos Creek and Lower Puget Sound basins. Runoff from the commercial area along S 320th Street, and to a lesser degree the West Campus Office Park, have resulted in erosion in upper tributary reaches and deposition of sediments and pollutants in the West Hylebos Wetland.
- ° Flows discharging from the Panther Lake basin have increased in frequency and magnitude in recent years and are predicted to cause damage to the West Hylebos Wetland and tributary 0014B between Panther Lake and the West Hylebos Wetland under future land use. Predicted flow increases from tributary 0014B account for 50 percent of the flow increase downstream of the West Hylebos Wetland.
- Loss of groundwater recharge in the Panther Lake tributary area may cause reductions in groundwater levels that sustain the West Hylebos Wetland in the summer months.
- Frequent flooding at several locations, including tributary 0013 at S 373rd Street, tributary 0014 at S 356th Street, and tributary 0014B at 1st Avenue S will dramatically increase in frequency and magnitude without mitigation.
- o The West Branch Hylebos Creek sub-basin had some of the highest metal (i.e., copper and zinc) concentrations measured during the King County SWM supplemental storm event monitoring program.

#### SECTION 4.3 EAST BRANCH HYLEBOS CREEK SUB-BASIN

#### INTRODUCTION

The East Branch Hylebos Creek sub-basin contains the largest portion of unincorporated King County in the planning area. As the least urbanized area of the six sub-basins, it is predicted to have some of the highest, unmitigated flow increases under future build-out land use. Although approximately sixty-one percent of the sub-basin is forested, existing levels of stormwater runoff in conjunction with highly erodable stream channels and urban pollutants have greatly reduced the aquatic resource that this sub-basin had historically supported.

#### SUB-BASIN DESCRIPTION

The East Hylebos Creek sub-basin, shown in Figure 4.3.1, includes the East Branch Hylebos Creek (tributary 0006) and its three major tributaries (0015, 0016, and 0016A). Tributary 0006 originates at Lake Killarney, whereas North Lake is the headwater area for tributary 0016. Bisected by State Route 161, the upper and lower portions of this sub-basin strongly contrast with each other. Upstream of the highway, the tributaries flow over a relatively flat upland till surface. The low channel gradients have yielded minimal stream erosion and only localized zones of fine-sediment deposition. Downstream of the highway, channel gradients steepen as the streams flow over an underlying deposit of easily erodible sand and gravel of the Vashon advance outwash. Sediments are carried to the mouth of the resulting ravine where they are deposited in the flat valley floodplain.

A major modification of the stream system occurred when the construction of I-5 diverted flow from the upper reach of West Branch tributary 0013 into the East Branch tributary 0016A. Residential development and other land-use changes, such as a quarry operation near the ravine by tributary 0006, I-5, an abandoned King County landfill, and the Weyerhauser Headquarters, have brought increased flows in the streams. Increased flows have caused some local drainage problems in the upper low-gradient portions of the sub-basin but have the greatest effect in the more erodible lower reaches in the ravines. The East Branch Hylebos Creek sub-basin generates over half of the estimate peak flow that enters the Lower Hylebos sub-basin. These flows, together with pollutants from urban areas and I-5, SR 18, and SR 161 road drainage, have degraded the aquatic resource of this sub-basin. Historically, excellent spawning and rearing habitat for salmonids existed in the ravine areas below SR 161. A small remaining spawning area in tribuary 0006, just north of Milton, is the sole remaining evidence of the magnitude of habitat loss attributable to urbanization.

# CONDITIONS

Existing damage is widespread along the tributary channels of this sub-basin even though Lake Killarney and North Lake provide some buffering of peak flows. Both lakes are currently providing significant flow attenuation, but because of their location in the headwaters, their buffering affects only a limited area. Without mitigation, increased future flows from those subcatchments (H7 and

4-12

H12), as illustrated in Figure 4.3.2 at build-out, will be nearly fifty percent, but the magnitude of increase is small, 3.5 to 4.5 cfs respectively, at the 100-year flow frequency.

Development along lake shorelines may experience future flooding such as occurred elsewhere in the planning area during the January 1990 storm, when lake levels rise in response to increased surface runoff. For example, the flood stage in the outlet channel of Lake Killarney currently reaches a depth of one foot on average once every 40 years. Under future conditions, this will occur on average once every 5 to 7 years.

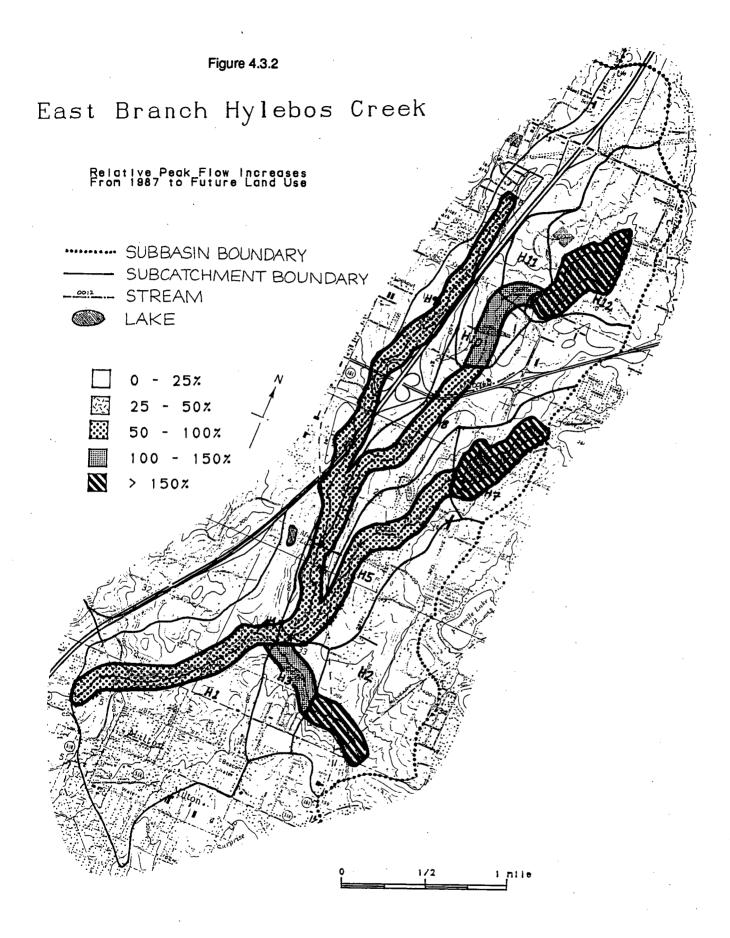
Flow increases from areas downstream of the lakes, especially subcatchments H5 and H8, are responsible for the majority of future peak flow increases in the East Branch Hylebos Creek. In general, future flows will as much as double current (1987) flows in all reaches of the East Branch tributaries with the exception of tributary 0015 (subcatchments H2 and H3) and tributary 0016 (subcatchments H10 and H11), which show over 150 percent increases. These dramatic flow increases and their resultant channel erosion, combined with poor quality water have severely degraded the streams in the East Hylebos Creek subbasin. These adverse conditions and the remaining resource areas of the subbasin are identified in Figure 4.3.3.

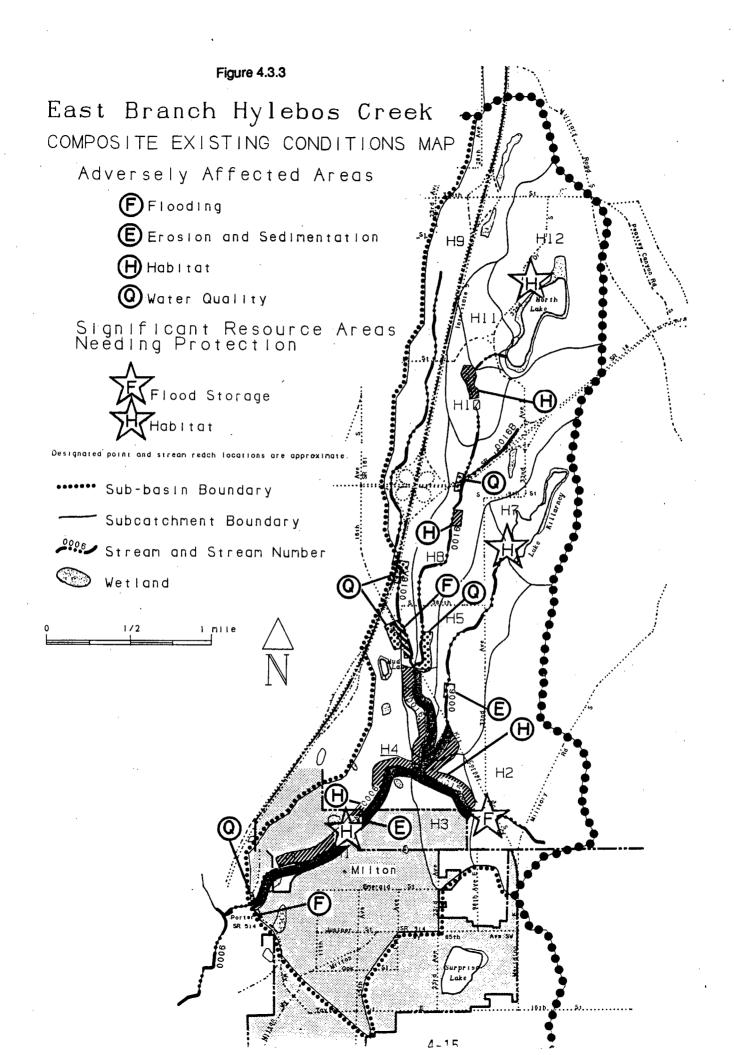
According to computer modeling, nearly a two-fold increase in peak flows has occurred since forested conditions. These increased peak flows have caused flooding in a few locations within the sub-basin and if unmitigated, future peak flows will worsen these problems and cause new areas of flooding.

During the January 1990 storm, flows from tributary 0016A flooded streets and one home in a portion of the subdivision at S 363rd Place and 20th Place S. The home had water nearly 4 feet deep in the first floor. Tributary 0016 also flows through a portion of this subdivision but its flood flow was attenuated during the storm by significant upstream detention at Evergreen Vale Apartments (RM 1.0). Existing detention ponds, such as the Evergreen Vale facility, do not have additional storage volume for the predicted future flow increases.

Peak flow increases within the individual tributaries will also cause road overtopping as culverts become undersized in comparison to the new, higher flows. Of the four streams that cross SR 161 (0006, 0015, 0016, and 0016A), tributary 0015 has the largest predicted increase (160 percent) and the others are expected to have from 50 to 100 percent increases. None of these four culverts are currently sized to handle the predicted future 25-year flow without mitigation. Tributary 0015 in subcatchments H2 and H3, and tributary 0016 in subcatchments H10 and H11, are areas that currently do not have severe flooding problems but in the future will most likely experience significant flooding.

Channel erosion in the steep gradient reaches downstream of SR 161 has resulted because of increased peak flows. Tributary 0015 west of 28th Avenue S descends through a narrow valley over numerous recent knickpoints, or vertical steps, in the channel bed. Small channel-bank landslides, and at least one recent large valley-side failure, are evident. Tributary 0016 appears to be undergoing recent and rapid degradation, particularly knickpoint migration, channel incision, and cementation of streambed gravels by fine sediment. These same reaches were described in 1986 as relatively problem-free by the Basin Reconnaissance report.





Tributary 0006, although only a secondary flow contributor upstream of its confluence with 0016, exhibits severe bank erosion, with failures commonly up to several feet high. Downstream of the confluence of 0006 and 0016, more limited erosion and active gravel transport gradually give way to deposition of progressively finer sediment, particularly at and downstream of the quarry at RM 5.8. Bank erosion from lateral migration of the stream channel still occurs, but the dominant process here and downstream to the confluence of the two branches of Hylebos Creek is deposition.

Because the channels are so steep downstream of SR 161, flows of almost any size will have high erosive potential. Incision in these particular streams is now dramatic, because the underlying geologic deposit is easily erodible sand and gravel of the Vashon advance outwash and because upstream development has substantially increased flows in these tributaries and so washes out the woody debris that previously would have stabilized the channel. That process is now pernicious—incision smooths the channel and eliminates debris from the water flow; the loss of channel roughness allows that same water flow to be even more erosive on the sediment of the bed and banks.

This activity is particularly well documented in this area. Along 0015 and 0016, three stations have been monitored for the last year in order to measure the rate of channel changes. Both were heavily impacted by the January 9, 1990 storm, so the results reflect the effects of large flow events as well as longterm discharges from urbanization. On 0015, a 5-foot-high knickpoint was measured near the confluence with 0006, in an area of erosion-susceptible sediments and abundant examples of existing stream-channel downcutting. The January 1990 storm completely obliterated this station; numerous hillside failures introduced much debris and sediment into the flow and completely altered the bed and bank characteristics. On 0016, two areas were monitored for channel downcutting. At the upstream site, just below the access road into the Regency Woods development off of SR 161, migration of a 4-5' high knickpoint occurred during both the period January-June 1989 and as a result of flows during the winter of 1989-90. In total, over 30' of upstream migration has occurred, with about 1/4 of that distance being covered in the first interval and the remainder during the January storm. Downstream a few hundred yards, a sewer pipe that crosses this tributary has provided a convenient marker for the channel bed. In the last 14 months (1/89-3/90), the bed has lowered almost 1.5 feet at this location, as measured by the clearance between the bottom of the (now-exposed) pipe and the channel bed. This degree of channel activity and degradation hold serious implications for any present or future efforts to stabilize or rehabilitate this section of the East Branch.

The consequence of increased flows and longer flow durations is continued bank erosion, further channel incision, and greater numbers of landslides within the ravine areas. As channel erosion occurs, more sediment is carried downstream to depositional areas in the floodplain valley causing clogging of culverts and siltation of spawning gravels.

The East Branch Hylebos Creek once provided excellent spawning and rearing habitat for anadromous fish up to approximately RM 7.0 on tributary 0006, RM 0.5 on 0015, and RM 0.4 on 0016, with some resident fish and cutthroat trout habitat in upstream headwaters. Increased flows by the additional tributary area of 0016A and development in the headwater areas have created an unstable flow regime that causes erosion and carries poor water quality. The quality and quantity of instream habitat has been further degraded by the removal of large organic

debris (LOD) and loss of perennial stream flow. Low or nonexistent summer flows, such as those which occur in the mid- and upper reaches of 0016 and 0016A, have resulted in severe reductions in the volume of juvenile rearing areas during the summer months. Tributaries 0006, 0015, and 0016 in the lower half of the sub-basin have a year-round groundwater supply from springs and seeps in the exposed layer of Vashon advance outwash in the ravine. This baseflow supplies cool and clean water to the reach, which in past history had been a spawning area for coho.

Future flow increases in a system already in an unstable flow regime will surely degrade remaining instream habitat. Degradation of rearing areas will occur not only from greater and more frequent flows but also in the further decrease in diversity from lack of large organic debris (LOD). As eroded soils are deposited in the lower reach of tributary 0006, gravel beds will be further silted, limiting successful spawning. In conjunction with these impacts is the increased concentration of pollutants may limit fish growth and production as well as directly cause fish kills. In December 1989, forty-seven yellow perch were found moribund or dead along RM 5.3 to 6.7 in tributary 0006.

As impervious surface area increases in the sub-basin and about its perimeter, less area is available for groundwater recharge. As recharging diminishes, baseflow may be lowered or become nonexistent, reducing the quantity and quality of instream habitat. Nonpoint pollutants, such as nutrients and suspended solids, typically increase as a basin urbanizes creating the potential for groundwater contamination in areas with high recharge zones. In this area, the aquifer known as the Milton-Redondo Channel is less susceptible to such contamination than other more shallow aquifers.

Four areas within the sub-basin have been identified that adversely affect water quality. The first is residential development and destruction of riparian zones immediately upstream of SR 161 and within the Evergreen Vale development, which are contributing high concentrations of nutrients, metals, and fecal coliform densities to the East Branch Hylebos Creek. Upstream of SR 161, along tributaries 0016 and 0016A, driveways have been built over the streams, and yards and gardens are immediately adjacent to the banks. Direct inputs of oil, greases, metals from automobiles, pet wastes, and nutrients are occurring. This subbasin had the highest mean nitrate + nitrite - nitrogen concentrations of any sampling site in the King County SWM storm event monitoring program.

The second is poor waste management practices at a bird pond, and sanitary and stormwater piping systems at Enchanted Village Amusement Park which resulted in extremely high concentrations of total phosphorus (0.70 mg/l) and fecal coliforms densities (37,000 organisms/100 ml) when sampled during storm events in late 1989 and early 1990. When these results were provided to the Park management, the stormwater system was connected to the sanitary sewer. One subsequent storm event sampling session indicated pollutant loadings fell within acceptable limits. It is unknown at this time, however, whether a significant problem still exists. Follow-up studies are needed to evaluate the status of the implementation of Best Management Practices and to conduct additional storm event monitoring. Also, the Federal Way Water and Sewer District and the Washington State Department of Ecology are needed to further evaluate any ongoing downstream impacts to East Branch Hylebos Creek.

The third is sediment loading and high concentrations of metals, which were sampled at the Regency Woods development near SR 161 and S 368th Way. Total

suspended solids concentrations (297 mg/l and 285 mg/l) were obtained from the development's retention/detention pond outlets. These samples were the third and fourth highest concentrations observed during the King County SWM storm event monitoring program. The high concentrations indicate that water is not being detained and is flowing directly through the ponds.

The fourth is lack of erosion control and encroachment into the repartial corridor along tributary 0006. The quarry operation is contributing high sediment loads to the stream system. These sediment loads are carried to the outlet of the ravine on tributary 0006 and are deposited in a low gradient floodplain area (RM 5.5 to 6.0).

The valley area of the East Branch Hylebos Creek experiences regional flooding which extends into the Lower Hylebos sub-basin. During the January 1990 storm, high flows flooded four homes near 5th Avenue in Milton. Flows at the sub-basin outlet (subcatchment H1) are predicted to increase by 76 percent. This significant future flow increase will excerabate the regional flooding already occurring in the southern end of the sub-basin as well as impact the Lower Hylebos sub-basin.

#### **KEY FINDINGS**

- The East Branch Hylebos sub-basin has some of the highest concentrations of pollutants sampled during the King County SWM basinwide stormwater monitoring program.
- Areas currently experiencing flooding are a subdivision along tributary 0016A upstream of SR 161 and the low gradient area in the lower reach of tributary 0006 near the sub-basin outlet.
- Two areas, tributary 0015 (subcatchments H2 and H3) and tributary 0016 (subcatchments H10 and H11), that currently do not have severe flooding problems are predicted to have over a 150 percent increase in peak flows at build-out. These increased flows will likely cause future flooding along tributary 0016 between SR 18 and SR 161 and along tributary 0015 near SR 161 and Military Road.
- Tributary 0015 near the confluence of 0006 is an area of erosion-susceptible sediments resulting in migrating knickpoints, channel downcutting, and numerous hillside failures.
- Increased flows, sediment-ladened gravels, pollutants, and trash in the stream channels have dramatically reduced the quantity and quality of aquatic habitats.

# SECTION 4.4 LOWER HYLEBOS CREEK SUB-BASIN

### INTRODUCTION

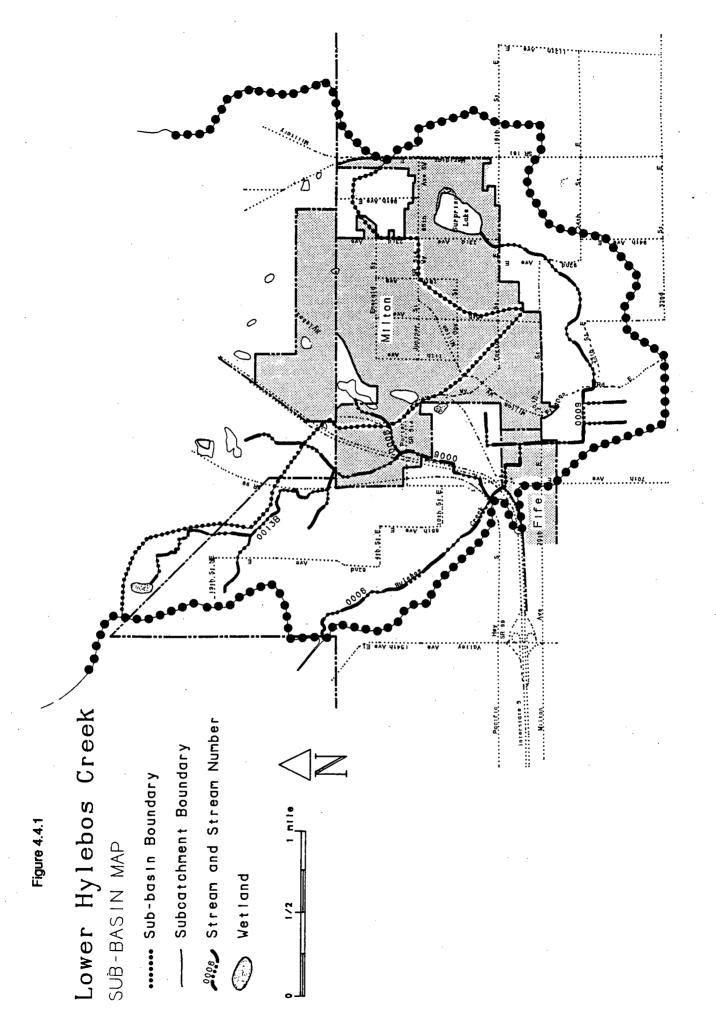
The Lower Hylebos Creek sub-basin shown in Figure 4.4.1 encompasses the portion of the mainstem tributary 0006 from its mouth at Commencement Bay to RM 5.4, tributary 0009 and Surprise Lake, tributary 0013B, and a short reach of tributary 0013 that extends to the King-Pierce County line. A detailed hydrologic analysis of the Lower Hylebos sub-basin is not a part of this report. However, limited field investigations were conducted and background studies were reviewed to gain understanding of the Hylebos Creek system in its entirety. A Stormwater Master Plan is currently being completed by James M. Montgomery and Associates for Pierce County Surface Water Management Division, which includes the Hylebos Creek system in both the incorporated and unincorporated areas of Pierce County. This Master Plan, expected to be available in August 1990, will provide more complete information on existing stormwater conditions in this sub-basin.

#### SUB-BASIN DESCRIPTION

The Lower Hylebos Creek sub-basin is characterized by a broad floodplain area that extends from Hylebos Waterway to an even wider, flat valley in its central portion. One plateau area borders the northern side of the lowermost reach of Hylebos Creek. Another plateau, split by the ravine which carries the Surprise Lake tributary, composes the most easterly portion of the sub-basin. Last modified by glaciation about 15,000 years ago, the plateaus are capped by Vashon-age till with the northerly plateau bordered by recessional outwash on its east and west slopes. The remainder of the deposits in the sub-basin are lake-bed silt and clay, deposited during the waning stages of the last glaciation, overlain by riverine deposits delivered from the East and West Hylebos branches as they descend from the much steeper gradient upstream reaches onto the flat, central lake-bed area. The lake sediments then merge with the Puyallup River alluvium near the confluence of the mainstem and the Surprise Lake tributary. This alluvium extends along the lowermost reach of Hylebos Creek bordering the southern edge of the sub-basin.

Some portions of this sub-basin have experienced tremendous changes in land uses, as illustrated by the conversion of the Puyallup estuary to a deep water industrial port. Once a saltwater estuary of Commencement Bay, this area has been filled along the first three river miles to create an industrial area for Tacoma and Pierce County. This industrial area continues within Pierce County along the mainstem (tributary 0006) to the confluence with the Surprise Lake tributary (0009). Low density and agricultural land uses are prevalent in the floodplain of tributary 0009 and along the mainstem. Draining to these reaches are residential development in the upland plateaus. These reaches are crisscrossed by the jurisdictional boundaries of Fife, Milton and King County. Along with these jurisdictions, waters of the Hylebos system are within the usual and accustomed fishing area of the Puyallup and Muckleshoot Tribes. Historically, coho, chum, and chinook salmon, as well as steelhead and cutthroat trout thrived in Hylebos Creek. The numbers of these species has dramatically declined as a result of land-use changes throughout the basin.

The effects of the urbanization are also seen in the degraded water quality and the increased runoff this sub-basin receives from not only its tributary area,



, ,

but also the entirety of the Hylebos system. Water quality in this sub-basin is dominated by cumlative impacts from upstream, I-5 and SR 99 runoff, development in Fife and Milton, and the industrial complex in Hylebos Waterway which is currently designated as an EPA Superfund clean-up site. This sub-basin experiences regional flooding in all stream reaches except the ravine area of tributary 0009 upstream to Surprise Lake.

#### CONDITIONS

The majority of flow delivered to this sub-basin orginates from the East and West Branches of Hylebos Creek. Hydrologic analysis for this report extends to the confluence of these two branches. Flow estimates for the mainstem of Hylebos Creek (RM 0.0 to 5.15) and the two tributaries interior to the sub-basin (0009 and 0013B) were not included in the analysis. The estimated flows at the confluence in combination with field investigations and previous studies are the basis for a qualitative review of the conditions in this sub-basin.

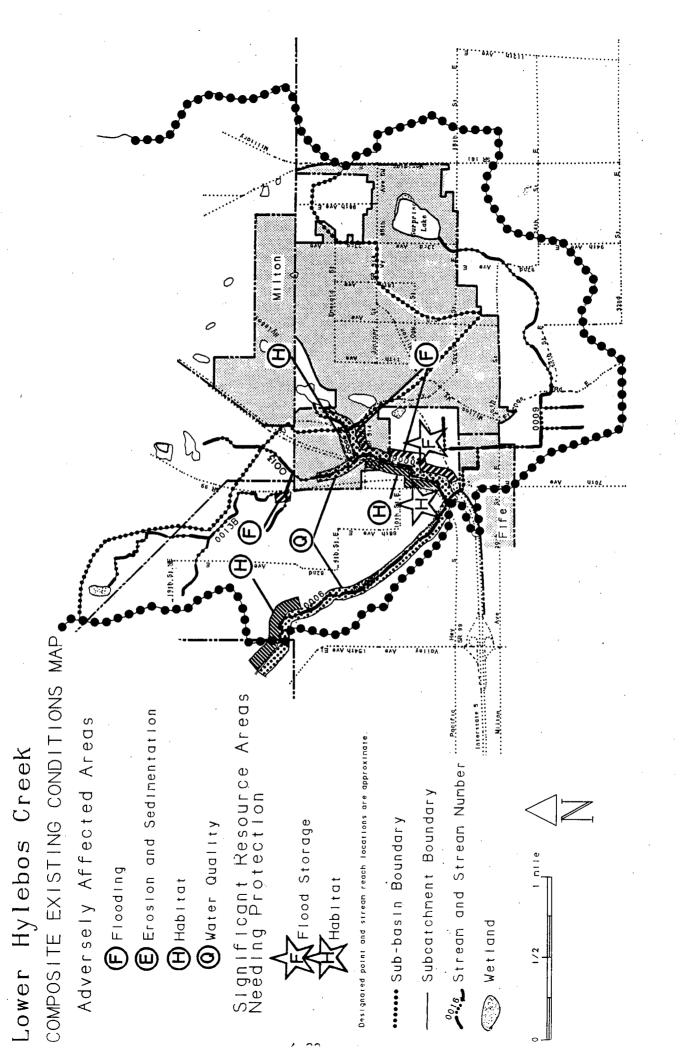
Resource areas such as flood storage and spawning and rearing areas for salmonids still remain in the sub-basin. These resource areas and locations where channel conditions have been adversely affected by development within and upslope of the sub-basin are shown in Figure 4.4.2.

Tributary 0013 above the confluence with the mainstem (tributary 0006) is in fairly good condition despite a model computed doubling of flows since forested conditions. Tributary 0013 between RM 0.44 and 0.85 contains some of the best fish rearing habitat in the Hylebos system as well as excellent wildlife habitat. Freshwater mussel beds, an indicator of good water quality, are present in this tributary at RM 0.06 and 0.50. Base flow sampling has shown that good water quality is present to support these mussels. However, sampling during storm events has indicated much lower water quality. Continued degradation of the water quality, particularly by increased concentrations of metals, will most likely result in the loss of these mussels.

Increased flows in tributary 0013 are somewhat ameliorated by wetlands that provide some flood storage. During the January 1990 storm, these wetlands were impacted by large amounts of sediment transported by erosive flows in tributary 0013B, which drains the rapidly developing Fife Heights area in the northwestern portion of the sub-basin. These sediments clogged culverts, causing flows to overtop and wash out road shoulders along SR 99. Gravels from the road shoulders and bedload from the stream were then deposited at the confluence of tributaries 0013 and 0013B.

The mainstem tributary (0006) upstream of its confluence with tributary 0013 has been severely degraded by increased flows and sediment deposition. The low gradient of this reach and tidal influence caused flooding of several streamside residences and deposition of fine sediments. These sediments and high concentrations of pollutants, such as total phosphorus, copper, and fecal coliforms, are generated from upstream sources in the East Hylebos Creek sub-basin. Toxicity, sediment, and channelization have severely reduced rearing habitat. This low-quality water combines with flows from tributary 0013 and is delivered to the wide floodplain area of the central sub-basin.

The wide floodplain of the central sub-basin area is an important element of flood storage. Recent flooding in January 1990 demonstrated the ability of this



area to detain flood waters and so not exacerabate flooding in the lower 4.5 miles of Hylebos Creek. Although two lanes of Interstate 5 were inundated, flooding west of the highway was not as severe. In general, overbank areas can provide refuge for fish during storm events and also allow sediments to settle out in slow, backwatered areas.

Although the valley areas of the sub-basin would naturally flood in the undeveloped condition, the sub-basin is now experiencing more frequent and larger volume floods. A 1981 Flood Insurance Study for Milton estimated the 100-year flow at the confluence of tributaries 0006 and 0013 as 310 cubic feet per second. The HSPF model computed this flow rate as 556 cfs based on 1987 land use, nearly an eighty percent difference. If detention for increased runoff is not applied, the future 100-year flow could increase to 970 cfs (see Figure 4.4.3). This increase in flow would increase greatly flood-related property damages and public risk. Higher water surface elevations from increased flows would be exacerbated further by predicted sea level rise and land subsidence in the sub-basin. Sea-level rise currently averages about one inch per decade. Together they may increase up to a total of 1.5 feet of relative submergence over the next 50 years (Shipman, 1990). Continued filling of floodplains will result in additional increases in water surface elevations upstream of the fill sites as well as produce locally greater velocities. Displaced volumes of water would contribute to increased flooding downstream.

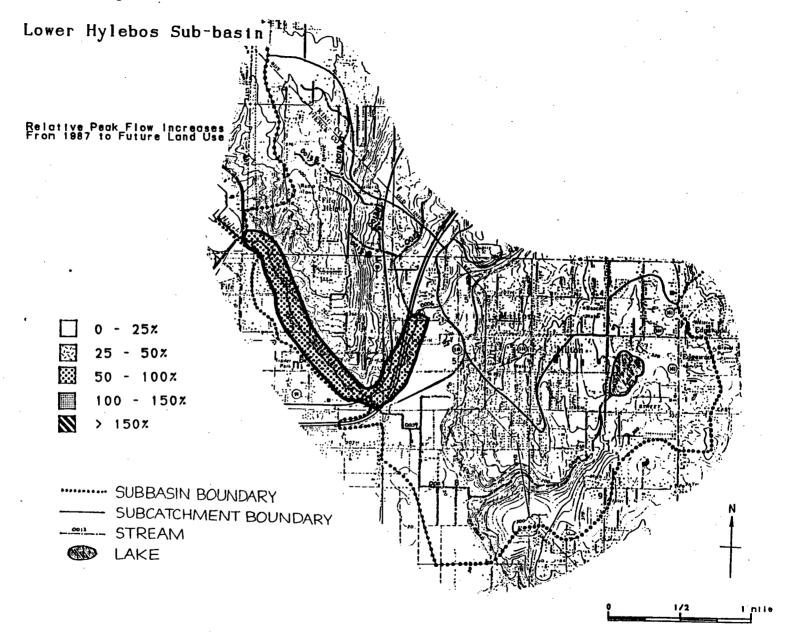
Replacement of natural floodplain and estuary areas with structures for human use inevitably increases flood hazards. Constrictions such as those imposed on Hylebos Creek at RM 4.5 (at I-5, SR 99, and a fill on the right overbank) are direct causes of flooding. Filling and channelization also destroy aquatic habitat. Major alteration of the physical stream system in conjunction with added pollutants and more frequent flooding have severely degraded the aquatic habitat. Once supporting several species of salmonids, only chum and coho are present and only due to the Puyallup Tribe's salmon fry out-planting program.

Hylebos Waterway and the lower reach of the mainstem (RM 3.0 to 5.0) serves largely as a transport zone for salmonids migrating to upstream spawning grounds. Near the mouth of Hylebos Waterway, there are some small patches of excellent estuarine habitat which is vital to juvenile fish during their transition from fresh to salt water. Incremental channel modifications, such as illegal filling and dredging, could reduce further the quantity and quality of salmonid habitat.

Efforts by the Puyallup Tribe and other interested parties to maintain and improve habitat will prove fruitful only if increased flows can be mitigated, floodplain encroachments prohibited, and pollutants eliminated. Unless new regulations are adopted and implemented quickly, the salmonid resource will continue to be sustained by juvenile out-planting, and most likely would experience a further decline or even total loss.

Pollutants within the lower reach of Hylebos Creek not only degrade aquatic habitat but are a public health risk. Commencement Bay was targeted for Superfund action in 1981, when the EPA listed 115 top-priority hazardous waste sites. Hazardous waste sites along Hylebos Waterway near RM 2.8 could be cleaned up in the future as a result of the Superfund Program; however, high concentrations of pollutants from new upstream sources could become a renewed cause for concern.

Figure 4.4.3



1

Previous water quality studies in Lower Hylebos Creek (see Section 3.7, Water Quality) have cited several significant problems. Contaminated commercial and industrial facilities, wastewater discharges, storm drains, and contaminated sediments are associated with industrial activities within Commencement Bay. High temperatures, low dissolved oxygen concentrations, and high dissolved arsenic, copper, mercury, and zinc concentrations are present in the Fife Ditch. High arsenic concentrations are also associated with the United States Gypsum and B & L Landfills, and the Surprise Lake drainage (tributary 0009).

Concentrations of pollutants, such as nutrients, metals, and suspended solids, will increase as the sub-basin and its upstream tributary area become more urbanized. With a reduction in open space and increased construction, there will likely be increased pollutant loadings of turbidity and sediment. Additionally, as onsite septic systems and sewer lines age, there is an increased potential for system failures. Highway construction on I-5 to accommodate High Occupancy Vehicle (HOV) lanes will add to construction impacts of sediments entering the stream and will contribute additional oil and grease from roadway runoff.

#### KEY FINDINGS

- Some of the best rearing areas and wildlife habitat in the Hylebos system exists in tributary 0013 along RM 0.44 to 0.85. Freshwater mussel beds exist at RM 0.06 and 0.50.
- \* Flooding in the central valley of the sub-basin has been exacerbated by increased flows, sediment deposition, and fill on floodplain areas.
- ° Future flows without mitigation are predicted to increased nearly 75 percent.
- Predicted sea-level rise and land subsidence may cause 1.5 feet of relative submergence in the next 50 years.
- The quantity and quality of aquatic habitat has greatly diminished from historical levels; minimal salmonid populations exist mainly from an outplanting program conducted by the Puyallup Tribe.
- Water quality is significantly degraded because of upstream pollutant sources, I-5 and SR 99 road runoff, and industrial and commercial activities within Commencement Bay and the Hylebos Waterway.
- Pollutants delivered to the sub-basin in combinations with hazardous wastes, specifically a EPA Superfund site along Hylebos Waterway, are a significant risk to public health.

### SECTION 4.5 LOWER PUGET SOUND BASIN

#### INTRODUCTION

The Lower Puget Sound basin is an amalgam of six individual streams and innumerable smaller drainageways. For purposes of this discussion the basin has been divided into three tributary areas—the North, Central, and South Lower Puget Sound sub-basins. All waters in these sub-basins flow from the upland plateau draining westward and northward into Puget Sound. Unlike most of the channels in the Hylebos Creek basin, the streams here flow through steeply incised valleys. Wave erosion on the shoreline following deglaciation of the region 14,000 years ago has established and maintained steep bluffs between the upland plateau and the Sound. These steep bluff faces are sporadically interrupted, primarily by stream valleys but also by a few zones of large-scale, and primarily inactive, landsliding.

### SUB-BASIN DESCRIPTION

The plateau and the bluff areas that together compose the Lower Puget Sound basin display very different geologic materials and processes. The plateau is underlain by till, deposited at the base of the ice sheet that last occupied the region. In many parts of the basin, particularly in the southwest, the till is overlain by sandy outwash deposited by water melted off the retreating ice sheet. This recessional outwash is up to several tens of feet thick in many areas, providing a pervious layer to absorb surface runoff and release it slowly above the relatively impervious till.

The bluff offers a view into the geologic layers beneath the till of the upland plateau. In the south and west, thick deposits of advance outwash were laid down by rivers emerging from the snout of the ice sheet as it first advanced. These sediments are now exposed down to sea level in places. Farther north, a sequence of older underlying deposits, both sandy and clayey, are sporadically exposed.

Landsliding in the Lower Puget Sound basin is an inevitable result of wave-steepened hillslopes and interlayered coarse and fine-grained deposits. Four such slides, all immediately adjacent to the shoreline, are particularly prominent and were first mapped almost 30 years ago (Waldron, 1961). Of these four, the largest (the "Woodmont Slide", at about S 274th Street) has a recent history of movement and has a number of occupied houses on its downdropped, and possibly still episodically moving, block. The others are presently undeveloped, but one that is platted (at about 9th Avenue SW) shows unequivocal evidence of historic movement, one just west was reactivated in 1986 by runoff from adjoining property, and the western-most one (at about 24th Avenue SW) is largely undisturbed. In addition, several zones of less discrete hillslope movement are evident in the basin. One, just north of Redondo, appears fully stable; the other, in the Buenna area, has shown some modest instability adjacent to seeps and drainage courses.

Existing land use in the basin has profoundly affected pattern and quantities of surface-water runoff. In many subcatchments, the upland plateau is almost fully developed, primarily in high-density single-family residences. Therefore, the local channels now display most of the problems that they ever are likely to

experience from development-induced flows. These subcatchments also provide a regional example of the consequences of inadequately mitigated urbanization—nearly barren flume-like channels with only limited opportunity for restoration or remediation.

Only parts of Joes Creek (0388) have thus far escaped the impacts of urban development: as a result, parts of the lower channel still provide some resource value. Yet these same subcatchments are predicted to experience some of the highest future flow increases in the entire basin planning area without effective mitigation of the urbanization impacts.

#### CONDITIONS

### North Lower Puget Sound Sub-basin

The two drainages in the North Lower Puget Sound sub-basin, shown in Figures 4.5.1 and 4.5.2, are in fair condition, protected from more intense degradation by only moderate upper basin development to date and an extensive outwash deposit at the headwaters of McSorley Creek (0381) which buffers flow increases. Some lateral erosion is evident along this creek, particularly between about RM 1.10 and its confluence with tributary 0382 downstream. Old hillside landslides are also evident at several locations along this valley, but in general they do not appear to affect the creek directly nor are their occurrences directly related to recent stream-channel erosion.

The slope of McSorley Creek undergoes a pronounced flattening as it approaches Puget Sound. For the lowermost thousand feet or more, the channel has built a delta out into the Sound, filling its valley with sediment brought down by the flow. It is a deposition zone for sediment, one which will persist irrespective of changes in future flow. Saltwater State Park is now constructed on that delta, which is generally inactive but which suffered significant innundation during the January 1990 storm. Deposition of sediment in the channel and at the constriction at the access road culvert forced water out of its normally confined path and across the lower part of the delta (and the lower part of the Park).

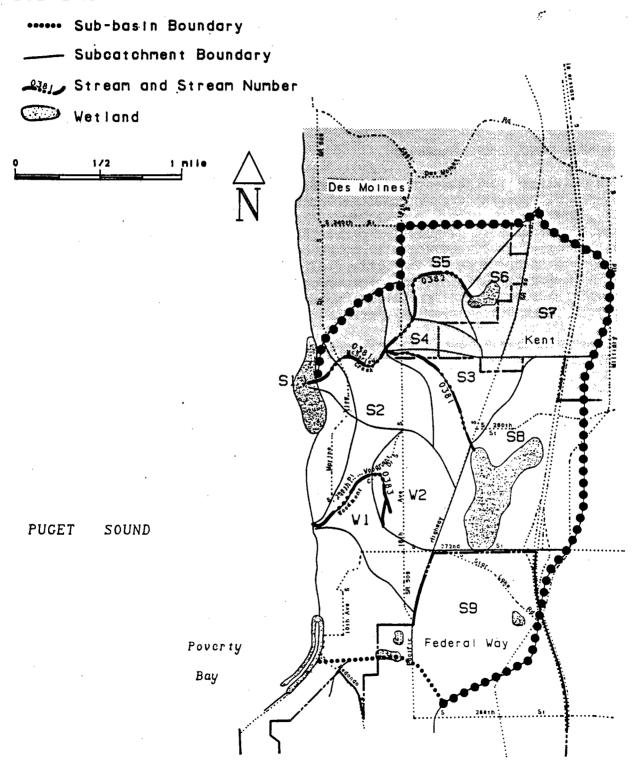
The upper part of this tributary is also the site of chronic flooding problems in the vicinity of S 272nd Avenue. Recent development on the south side of that road has channelized drainage, decreased infiltration, and increased runoff peaks and volumes. As a result, previously undefined surface and subsurface flow now overwhelm the drainage detention and conveyance system in this area, leading to numerous complaints annually and a now pending King County Drainage Investigation study.

Under normal conditions, tributary 0382 contributes relatively little to either the flow or the sediment load of tributary 0381, but upstream of their confluence recent development in the headwaters of tributary 0382 has resulted in a very high concentration of fine sediment in the gravels on the bed of the channel. In addition, a drainage outfall from the Midway Landfill detention pond which collects storm flows from both the Landfill and I-5 enters the stream system on tributary 0382 just above its confluence with 0381. The contribution of this discharge to flow in McSorley Creek is under dispute, with regard to the January 1990 flooding of Saltwater State Park. No additional information is presently available.

Figure 4.5.1

# North Lower Puget Sound

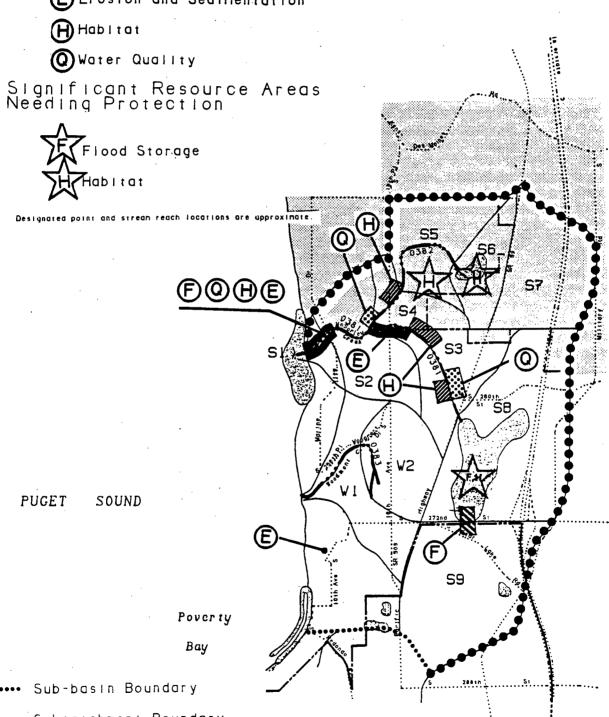
SUB-BASIN MAP



# North Lower Puget Sound COMPOSITE EXISTING CONDITIONS MAP

Adversely Affected Areas

- (F) Flooding
- (E) Erosion and Sedimentation



Subcatchment Boundary

Stream and Stream Number ورودي

Wetland

The January 1990 storm also plugged the culvert crossing of tributary 0382 under 20th Avenue S, near S 245th Place, with debris and sediment. The out-of-channel flows damaged both public and private property at the road crossing and for several lots downstream.

Water quality in McSorley Creek strongly reflects existing land use. This creek showed the highest concentration of total phosphorous of any station in the 1989-1990 King County SWM storm event monitoring basin-wide. High total phosphorus and copper concentrations, and fecal coliform densities in tributary 0381 at S 260th Street (Station QM2) probably originate from SR 99 runoff and impervious, commercial, and multifamily land-use areas immediately east. This station was always observed with oily sheens and hydrocarbon smells during storm events.

High fecal densities, nutrients (e.g., nitrate + nitrite - nitrogen and total phosphorus), and metal (e.g., copper, lead, and zinc) concentrations in tributary 0382 at S 251st Street and 16th Avenue S were measured at Station 11 (City of Kent) and probably originate from: 1) high-density single-family residences west and north of 20th Avenue S; 2) impervious/commercial areas west of 20th Avenue S; and 3) SR 99 runoff and associated impervious areas. Since monthly monitoring by the Green River Community College began in 1986, this station has experienced very low dissolved oxygen (D.O.) concentrations during the summer months, with typical values of about 5 to 7 mg/L and as low as 4.7 mg/L in 1987.

Fish habitat is limited in McSorley Creek. There are good spawning gravels and cobbles throughout much of the channel from RM 0.20 up to the crossing of SR 99 (RM 1.41), which forms the upper extent of salmonid habitat. The lower one-tenth mile has much higher fines than occurs in most places upstream. Canopy and overhanging vegetation is good upstream of RM 0.20 where the stream is buffered by wide slopes of mixed second-growth forest and brush. However, most of this system lacks large organic debris (LOD) and pools.

The mouth of McSorley Creek to RM 0.90 is dominated by shallow riffles with virtually no pools. A series of mass failures has occurred from RM 0.30 to 1.20: they vary in volume from a few hundred to over 10,000 cubic feet. The channel is choked by several dozen recent tree falls upstream of RM 0.90 for 0.2 miles due to the 1989 and 1990 floods, one of which may be impassable to fish at all There is no cover over most of the lower 0.20 miles through the picnicking and camping areas of Saltwater State Park. From RM 0.12-0.20 there are 2-3' high berms of cobble, gravel, and sand alluvium, which was presumably dredged out of the channel since the January 1990 flood. These berms have not yet eroded into the channel significantly but are likely to do so over time. This potential sediment source, together with unstable and unvegetated deposits associated with the new failures from RM 0.30-1.20, will continue to add to the existing load in the stream. Most of these failures will also likely enlarge during future storms. The system will become increasingly riffle dominated, and the small pools remaining in the upper reaches will decrease in size with aggradation. Although four juvenile salmonids were seen near the mouth of tributary 0382 in April 1990, even limited future degradation would represent a significant impact to the marginal habitat that remains.

Woodmont Creek (tributary 0383) functions as little more than a conveyance channel. Owing to its limited drainage area and resistant substrate, flows have not significantly incised the channel deposits. Filling of the stream valley for placement of Woodmont Beach Road, however, has severely constrained the

historic stream channel and so encouraged lateral migration and resulting bank failures. Local bank armoring has been apparently successful at reducing normal maintenance, but the storm of January 1986 eroded a portion of the roadway surface. Other major problems have been neither identified by this investigation nor reported by stream-side residents.

Flows in all these tributaries are predicted to increase by about 50 percent or more without mitigation (see Figure 4.5.3). As a result, 100-year flow events under 1987 conditions would increase in frequency 10- to 20-fold in the future.

## Central Lower Puget Sound Sub-basin

Both of the major channels in this sub-basin, shown in Figures 4.5.4 and 4.5.5, have been heavily impacted by development in their upstream reaches and along the channels themselves. Simulated flow increases from past development are among the greatest in the basin plan area, with increase of 3- to 4-fold common over most of the channels' length. These channels also have the steepest gradients of any in the basin planning area, with average slopes approaching 10 percent over their lowermost mile. The erosivity of this (greatly increased) water flow is therefore maximized. The use of these channels by anadromous fish has probably been severely curtailed by such gradients, even in predevelopment time.

Redondo Creek (0384) has three distinct segments. Between Steel Lake and SR 509, the channel gradient is dictated by the low slope of the upland till surface. Both sediment transport and erosion problems are quite low. Downstream of SR 509, the channel incises into easily erodible deposits of the advance outwash as it simultaneously increases in gradient. As a result, incision is dramatic and recent; tree roots entirely bridging the top of the channel, presumably below the ground level at some time in the past, are now suspended four feet above the channel bottom. Predicted future flow increases of about 25 percent along this reach will intensify this activity.

In its third segment, downstream of about 13th Avenue S, the channel is severely constrained by the roadway. Bank armoring, including several hundred feet of piping, have been largely successful at limiting further erosion downstream to Puget Sound. Yet the steep deposits on the flanking hillsides remain largely unprotected from uncontrolled upland drainage, which has resulted in a roadway-blocking slide in January 1986 originating along a utility trench at RM 0.40 and active incision up to 20 feet deep on the north valley walls at RM 0.50. The lowermost 500 feet of channel are piped, likely presenting an impassible barrier to migrating fish. Upstream of this barrier, habitat conditions are little improved, with only a short reach of relatively undisturbed channel at about RM 0.20.

Cold Creek (0385) is either piped, channelized, or actively incising along nearly its entire length. Because of substantial flow increases from dense development in its headwaters, many reaches of the creek have been stripped of their diversity: pools, riffles, and bends have been largely replaced by steep bare walls and a uniform planar bed. The numerous pipe and culvert inlets have restricted the magnitude of channel incision by holding the bed elevation constant at those points. This stabilization, however, has been at the expense of other stream functions and potential values. Modest fish habitat persists for about 1/3 mile upstream of the Redondo Sewage Treatment Plant, although the

Figure 4.5.3

North Lower Puget Sound Sub-basin

Relative Peak Flow Increases From 1987 to Future Land Use

0 - 25%

25 - 50%

50 - 100%

100 - 150%

> 150%

··· SUBBASIN BOUNDARY SUBCATCHMENT BOUNDARY

STREAM

LAKE



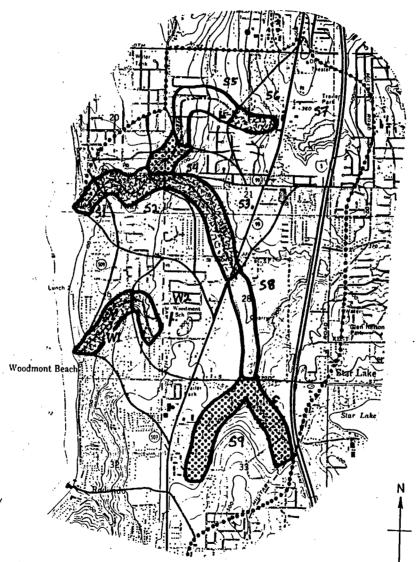
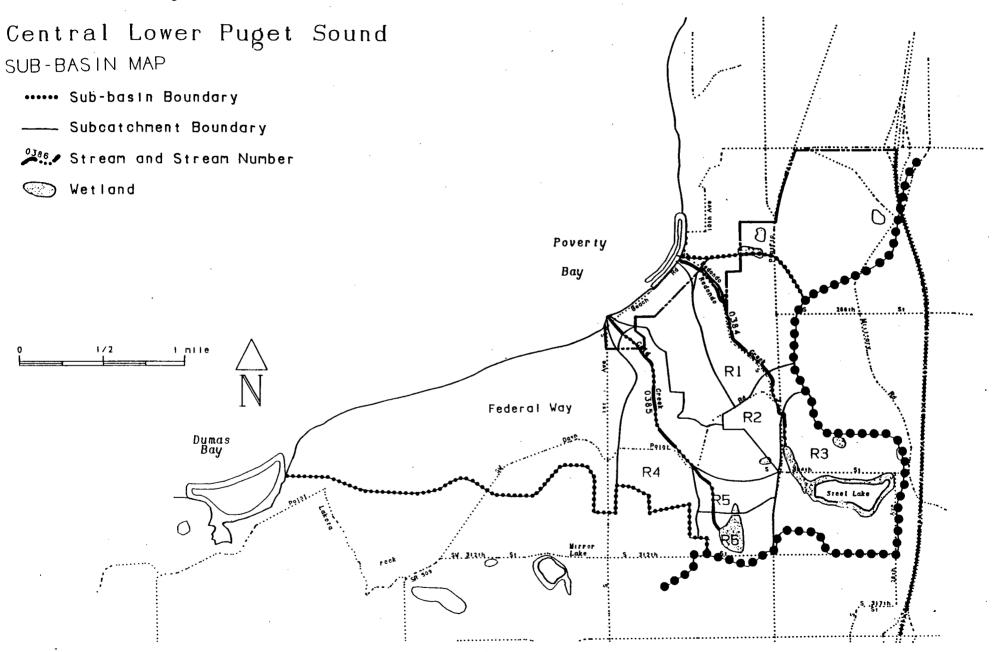
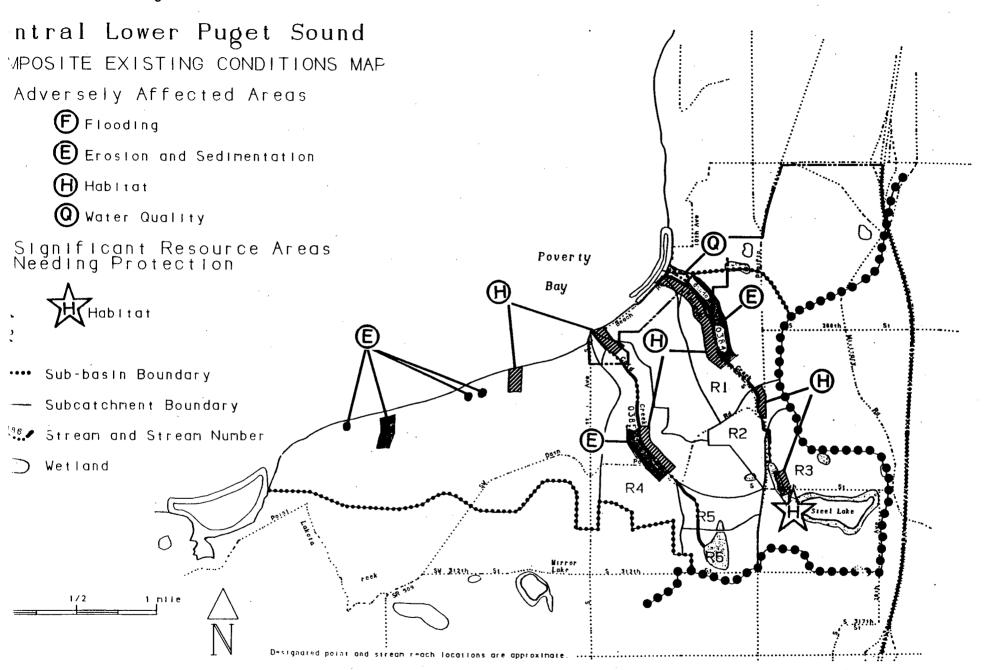


Figure 4.5.4





weirs and pools in the channel here may be a migration obstacle and the channel through the mobile home park is devoid of cover. Predicted future flow increases are not substantial along this tributary, but even existing flows are sufficient to maintain active upstream erosion and consequent downstream deposition (see Figure 4.5.6).

A variety of other problems have occurred in and adjacent to this sub-basin but are not associated with any named channel. One in particular, the washout of a private culvert at the base of 20th Avenue SW in Adelaide, reflects the potential for sediment mobilization, downstream deposition, and subsequent blockage of constructed drainage facilities in any of these small but steeply sloping drainageways.

Water quality conditions in this basin affect both streams and lakes. High measured fecal coliform densities and copper and zinc concentrations probably originate from high-density single-family residences (Station QC3, Figure 3.7.1b), and from SR 99 runoff and associated impervious and commercial areas (Station QC2, Figure 3.7.1b). Station QC2 was always observed with oily sheens and hydrocarbon smells during storm events. A gasoline service station at the corner of SR 99 and SR 509 is immediately upstream of Station QC2 on Redondo Creek; petrochemicals were apparently disposed here in the 1940s as well. This sub-basin had the highest mean concentration (75 mg/L) for total suspended solids of any in the 1989-90 storm-event sampling basin-wide.

Steel Lake, the 46-acre lake at the head of Redondo Creek, is characterized by tea-colored water and shallow depths. Historically, this lake has been classified as mesotrophic (i.e., middle-aged when concentrations of phosphorus and algae levels increase, and water clarity decreases). The 1988 data used to classify the lake indicate a similar condition (Metro, 1988). A recent (February 17, 1990) sample from Steel Lake at 1-meter depth revealed a relatively high chlorophyll a concentration (13.95 mg/L). This level usually characterizes algal blooms and may be associated with lake turnover, but this is not an expected late-winter occurrence. Although surrounding development is almost complete, the lake may continue to degrade over time as the bottom sediments accumulate additional phosphorus and then release it annually to overlying waters. The lake is not deep and so not well-suited to buffer additional sediment loading.

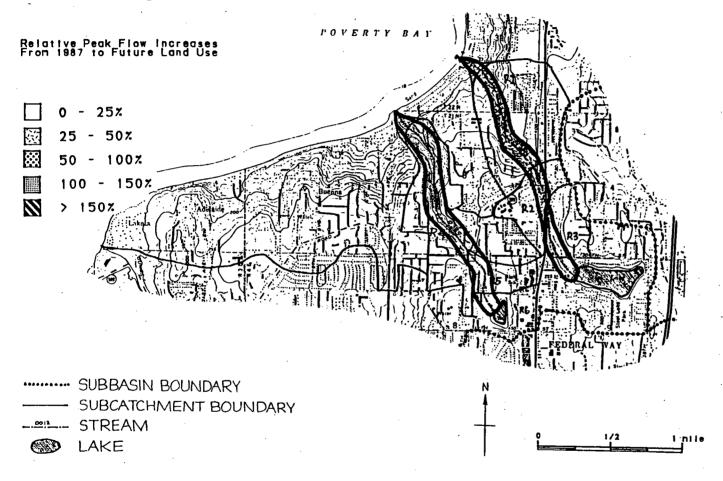
#### South Lower Puget Sound Sub-basin

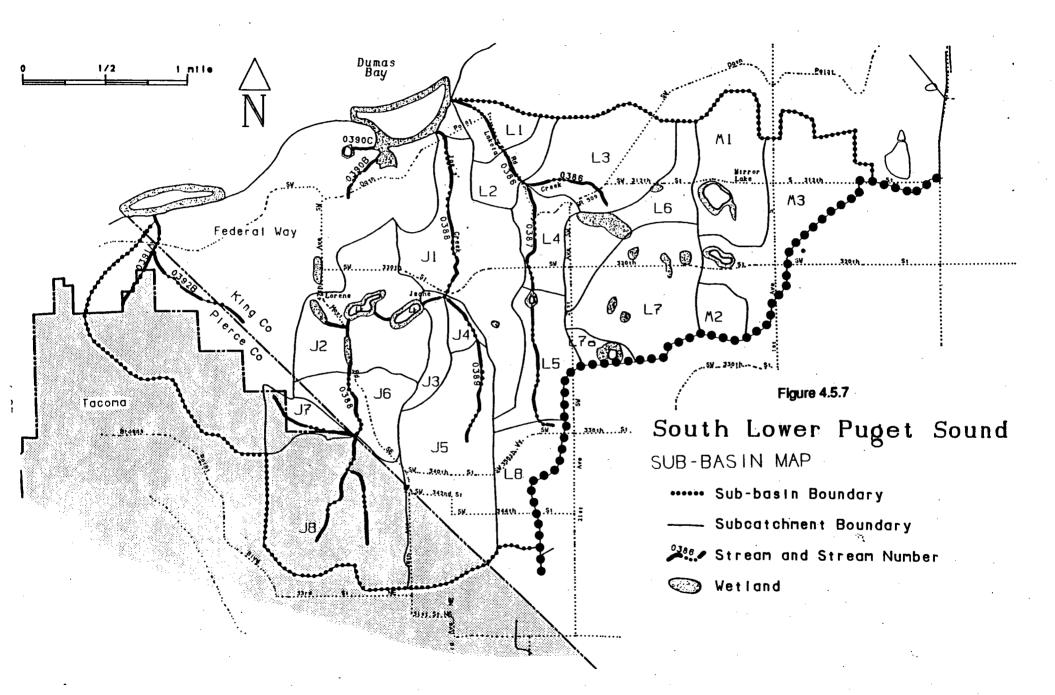
The streams of this sub-basin, shown in Figures 4.5.7 and 4.5.8, drop steeply off the till-and-outwash upland plateau through about 200 feet of underlying ero-dible sandy outwash deposits. As elsewhere in this basin, and in the region as a whole, erosion susceptibility is heightened wherever these deposits are exposed along the course of stream channels. In a sub-basin where development activity has been high, such problems can be very common. Flows in Lakota Creek and Joes Creek are among those showing the greatest increases over predevelopment conditions, and thus the problems now evident are likely to approximate future conditions as well. Localized exceptions to this pattern in upper Joes Creek, however, suggest that some areas are still likely to experience dramatic future impacts (see Figures 4.5.9).

The tributaries of Lakota Creek (0386 and 0387) exhibit markedly different levels of channel activity and erosion. Above the confluence of the two forks, tributary 0386 exhibits only modest degrees of erosion over most of its length,

Figure 4.5.6

Central Lower Puget Sound Sub-basin





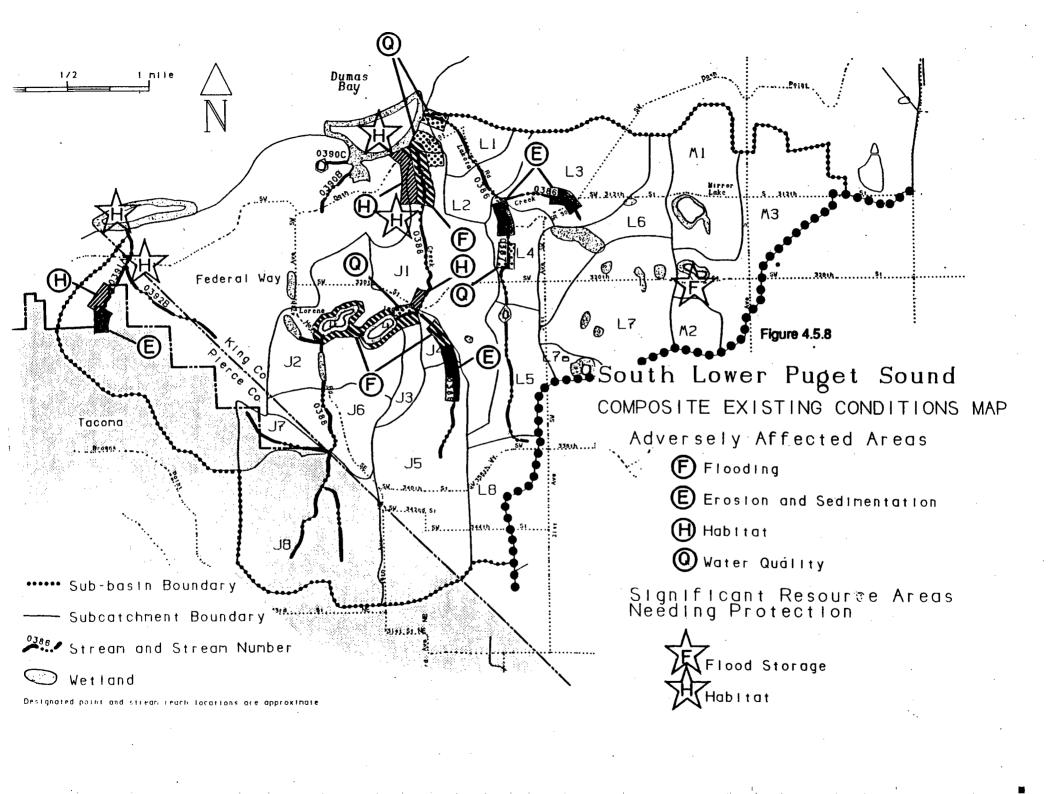
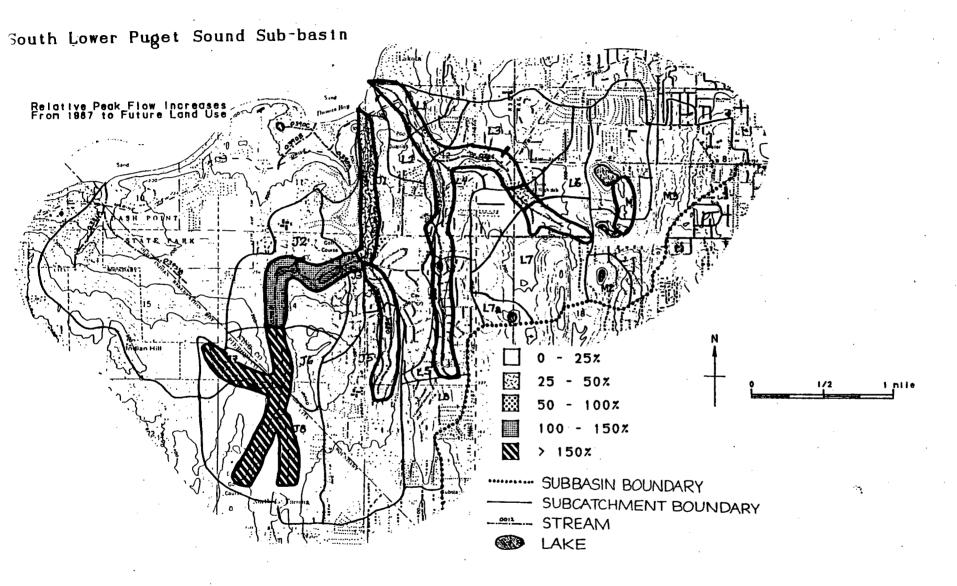


Figure 4.5.9



mainly local bank failures. Incision is quite active, however, in the first several hundred yards downstream of its crossing of SR 509 at Lakota Junior High School. Channel erosion is much more common along tributary 0387 downstream of S 320th Street, particularly alongside Decatur High School and again downstream of SR 509. Neither of these branches are likely to see greatly increased levels of erosion, because their headwater areas are largely built out. Flow increases of at most 10-20 percent are anticipated.

Downstream of the confluence at SR 509, reduced channel gradients drop the stream below a level of chronic erosivity. One significant hillside failure and a number of zones of minor bank erosion occur along this reach, but most of this activity is simply associated with the attempted lateral migration of the stream between constraining banks, occurring where the stream's gravel load is depositing onto narrow point bars and consequently deflecting flow. The potential for stream restoration would be high if not for the physical constraints imposed by sharing the valley bottom with SR 509 and the Federal Way Sewer and Water District sewage treatment plant. In addition to physical constraints, the high-flow bypass pipe of the treatment plant attracts up-migrating fish away from the channels; the upstream culvert inlet provides a locus of chronic sediment deposition. Nevertheless, some fish and spawning activity have been observed in these lower reaches, with sediment deposition at the bypass culvert inlet providing some protection to habitat downstream.

Upstream of the western tributary of Lakota Creek, the closed basin around Fisher's Bog and Mirror Lake provides significant infiltration of water to subsurface aquifers. Under existing conditions, that basin is simulated to overflow at about the 1.3-year event (30 out of 39 years); it drains into the Lakota High School wetland at the head of tributary 0386, site of a proposed regional detention pond (under design 1990). This area contributes up to 25 percent of the total outflow from the wetland, with decreasing proportional contribution as storm magnitude decreases. Under future land-use conditions, that same overflow is predicted to continue at nearly the same frequency, with discharge in 33 of 39 years. The relative percentage of contribution to the wetland is about the same, and the absolute discharge increase is only 15 percent above existing conditions. In contrast, the simulation under forested conditions showed overflow discharge in only 6 of 39 years.

Joes Creek (0388 and its tributary, 0389) includes the largest drainage area in the Lower Puget Sound basin. It flows through a canyon almost completely walled and floored in sand of the Vashon advance outwash; its upland path also has exposed a significant area of this same material through Olympic View Park along tributary 0389. As elsewhere in the region, channel degradation is well-correlated with zones of this deposit, particularly where the surrounding basin area is highly developed.

The upper part of tributary 0388 is mainly floored in low-gradient till, in a basin that under 1987 conditions had only begun to develop significantly. As a result, modeled flows are small and historic stream activity has been quite minimal. In the southwestern part of the basin, however, future development is predicted to yield the greatest flow increases of any in the basin planning area, resulting in greater than doubling of flows in the downstream channel. Some of these future impacts have already been realized as a result of development since the 1987 calibration period, demonstrated during the January 1990 storm when the level of the Twin Lakes increased sufficiently to flood several homes. Increased flows, and perhaps also loss of lake storage from sedimen-

tation, as a result of upstream development probably contributed to the resulting damage.

Tributary 0389 is floored almost entirely in till, but it locally has incised fully through that deposit to expose a "window" of the underlying sandy advance outwash deposits through Olympic View Park. In this area, chronic incision and consequent downstream deposition has initiated efforts to slow the rate of channel downcutting. Gabion weir dams with overflow structures were built in 1986 to reduce flow velocities, trap sediment, and stabilize the channel. Downstream of these weirs, however, the severity of channel downcutting increases dramatically, probably due to sediment starvation of the channel bed without concurrent reduction in flows. Downcutting is halted only by the piping of the subsequent stream reach beneath SW 325th Street, although the constriction of channel capacity by this culvert has resulted in flooding of the roadway and adjacent property.

Downstream of the confluence with tributary 0389 and the culvert outfall below SW 320th Street, the channel is relatively stable, although an abundant sand supply has resulted in heavy deposition into the gravel bed. Erosion is limited in part because of the large amount of woody debris in the stream and in part because of lower channel gradients. Where flows have been diverted against the banks, however, the effects of increased flows on erodible material is rapid and dramatic, particularly at RM 0.30 where a debris jam has deflected the flow and initiated a large sidehill landslide. Although coarse sediment derived from stream action is deposited on the delta at the mouth of Joes Creek, fine sediment is flushed out farther into Dumas Bay. Continued and accelerating stream erosion along this creek, and in the others draining into this bay (Lakota Creek and tributary 0390), will further the degradation of this near-shore environment.

Existing fish habitat in the Lower Puget Sound basin is largely concentrated in this sub-basin; and most of that can be found only in the lowermost mile of Joes Creek. Most of the lower reaches below SW 320th Street in this tributary have fair to good spawning and rearing habitat. Much of tributaries 0388 and 0389 above SW 320th Street are culverted or sewered; this is the current upstream limit of viable salmonid habitat. The major limiting habitat factors from RM 0.0 to 1.02 are decreased pool volumes due to aggradation, and debris jams, which constitute potential migration barriers. Medium to high amounts of large organic debris (LOD) throughout this lower mile create good cover and complexity, contributing greatly to the stability of the channel. More localized patches of good habitat exist upstream of Twin Lakes, but they cannot presently be accessed by fish.

The channel substrate in the lower mile is predominantly pebbles and cobbles. Localized areas of heavy sand deposition in pools and bars reflect the impact of upstream development, but good spawning occurs through most of this section. Fines are generally less than 20 percent in riffles. There are about eight pools from RM 0.18 to 0.42; all but one are less than 12 square feet in area and 1.5 feet deep. All the pools in this lower mile of Joes Creek are formed by LOD, usually half-buried old cedar logs.

From RM 0.06 to 0.89, Joes Creek runs through a valuable undisturbed corridor 200-500 feet wide of second-growth cedar, hemlock, and Douglas fir, along with alder and cottonwood. The valley floor averages 50-80 feet wide with a 6-12 foot channel width. Trees are up to 28 inches diameter. Dominant understory

species are salmonberry, thimbleberry, vine maple, and sword fern. Slopes are up to 150' high with inclinations of 60 to 90 percent, a testament to the stabilizing effects of this well-vegetated corridor.

Although conditions in this creek are quite good relative to the rest of the basin, significant problems are still evident. Pools are being filled through recent aggradation, largely as a result of bank failures, and several LOD jams may be fish-migration barriers. Three new or recently enlarged slope failures occur from RM 0.80 to 0.86; others occur at RM 0.14 and 0.30, with estimated volumes of up to several thousand cubic feet. Smaller but more numerous failures are located above RM 0.88, as the channel impinges against the fill of the golf course driving range. Wood and metal debris in this area also choke the channel. Several debris jams, composed of medium and large trees and logs, form more pronounced migration barriers farther downstream during most or all flow stages. Probable low-flow barriers are found at RM 0.32 and RM 0.48; jams at RM 0.80 and 0.84 are probably impassable at all but storm flows. An LOD jam at RM 0.66 presents a 1.75-foot-high cascade and is probably impassable at all flows.

Continued aggradation and pool filling is likely, due to the exposed sandy soils in the cut banks and slope failures of the upper reaches of the lower stream mile. Flushing of existing instream fines probably cannot occur for several years (if ever) until and unless these banks heal over. However, higher peak flows resulting from further urbanization and reduced storage upstream could increase both sediment loading and the rate of bank failures. Existing jams will most likely grow or become more watertight with continued aggradation, potentially causing more significant backwatering and undercutting. New development, such as a newly cleared housing development above the north slope at RM 0.72, could provide major sediment input if detention ponds are undersized or conveyance facilities fail.

The other, smaller streams in this sub-basin (tributaries 0390, 0392B, and 0391A) display a suite of both channel problems and habitat opportunities. All three branches of tributary 0390 pass through the wildlife sanctuary at Dumas Bay and provide valuable wetland and upland habitat. Each branch has good canopy and understory cover, but none have any significant LOD, pools, or spawning gravels. The majority of all three channels are stable, with short reaches of downcutting in the middle and west forks. The west fork is impassable due to a 18" drop at the outfall of a 24" culvert, whereas the middle and east forks may provide some fish habitat at flows above baseflow.

In contrast, the Dash Point State Park tributaries (0392B and 0391A) provide more extensive fish habitat but also are experiencing more severe problems. In 0392B, good to excellent canopy and understory cover is found from RM 0.10 to RM 0.42, which is the upper limit of salmonid habitat due to an impassable falls and overly steep channel gradients. LOD is sparse until RM 0.24-0.42, where woody debris stabilizes the banks and provides good instream cover. Some pockets of fair spawning gravels exist upstream of RM 0.10. Except for a creek-paralleling hiking trail, the corridor from RM 0.10 to 0.42 is isolated and provides excellent upland habitat, with narrow wetlands just adjacent to the channel. Good canopy is also found along the lowermost 0.2 miles of tributary 0391A. Both channels, however, suffer from a paucity of pools. In addition, tributary 0391A is experiencing severe erosion in its headward reaches from development-induced flow increases, with attendant sideslope failures and introduction of more sediment into the stream.

Water quality conditions in this sub-basin are similar to but more severe than those observed in the Central Lower Puget Sound sub-basin. This sub-basin was the "worst polluted" sub-basin (considering mean concentrations of 11 variables) during the storm event monitoring program for the entire study area. High fecal coliform densities and metal concentrations were detected in the upper reaches of both Joes and Lakota Creeks. This sub-basin had the highest geometric mean density for fecal coliform and the second highest mean concentration (73 mg/L) for total suspended solids. High concentrations of total phosphorus were also observed at the mouths of both Joes and Lakota Creeks. These high levels are probably originating from the large area of high-density single-family land use in both drainages. Phosphorus is closely associated with high sediment concentrations, which were similarly observed in the steep lower reaches of both creeks. Increased future flows in this creek will probably add to this problem.

Impervious areas associated with large single-family and multifamily developments are contributing large flows and high sediment loads to the Twin Lakes. The lakes are acting as a sink for these contaminants. As a result, acceleration of the eutrophication (i.e., increased nutrient loading and associated aging) is probably ongoing in these lakes. Because of relative flushing rates, Lorene Lake is likely to experience significant water quality problems more quickly than Jeane Lake. Other lakes in this sub-basin also receive nutrients, but whereas the volume of water is five times larger in Mirror Lake than in either of the two Twin Lakes, the annual phosphorous loadings are roughly equivalent. Thus problems are more likely in these two smaller lakes.

Although not a part of the freshwater system that forms the major focus of this study, Dumas Bay is a unique resource of Lower Puget Sound and is directly impacted by drainage off the land surface. Dumas Bay is an 253 acre intertidal sandflat habitat that receives discharge from five small streams that drain the upland plateau: Joes and Lakota Creeks, and three unnamed streams (0390A, 0390B, 0390C). Dumas Bay and similar estuarine embayments throughout Puget Sound provide important nursery, breeding and feeding areas for a variety of species, many of commercial interest, others of importance for their ecological role. Despite its value, however, extensive development has occurred on the bluffs and slopes surrounding the bay and has encroached on the bay's shoreline and on the northern edge of the freshwater marsh. In particular, delivery of sediment to the marsh has increased with increasing disturbance of the uplands and slopes surrounding the ravines of streams 0390A and 0390B. The deep marsh, with its open water habitat, is particularly vulnerable to this deposition.

The bay itself has suffered direct impact from shoreline protection measures such as bulkheading and rip-rapping, especially along its northern shoreline near the mouths of Lakota and Joes Creeks. Often, these techniques have been employed in an attempt to stabilize the toe of the steep bluffs that rise above the beach. Slope failures remain quite common in this area, however, and may be exacerbated by slope clearing and improper drainage over the bluff edge.

In the northeastern quadrant of Dumas Bay, near the mouth of Lakota Creek, a wastewater treatment plant discharges some 1,000 million gallons per year of secondary sewage treatment effluent into the bay. Until 1988, the plant discharged wastewater that had undergone only primary treatment. Though convincing evidence is lacking, the plant outfall may be a contributer of nutrients, metals and coliform bacteria to the bay, together with nonpoint sources documented in this study.

The bay is permanently closed to commercial shellfish harvesting, as are all eastern Puget Sound beaches from Meadowdale in Snohomish County to Commencement Bay in Pierce County, due to fecal coliform bacteria contamination.

#### **KEY FINDINGS**

- Deposition in Saltwater State Park is a pre-development condition that has progressed and will worsen with increasing flows in McSorley Creek and its tributaries (0381 and 0382).
- Observation of Property of Redondo Creek (0384) has been active and will accelerate. Erosion in other parts of this sub-basin, particularly associated with smaller drainageways and ill-diverted runoff, has been locally substantial.
- Increases in flows in Lakota Creek (0386 and 0387) have caused zones of substantial stream damage. Future development in this sub-basin is not high, but downstream constraints limit stream restoration possibilities.
- \* Flooding in the Twin Lakes area on Joes Creek (0388) is a recent phenomenon, probably caused by a combination of flow increases and sediment deposition from upstream development. Future development without mitigation will lead to dramatic flow increases, with the frequency of flood-causing events becoming about 20 times more common.
- Ones Creek currently contains the best fish habitat in the Lower Puget Sound basin, but future flow increases predicted for the lower canyon area will severely degrade the channel there.
- Water quality, particularly in the South sub-basin, has been severely impacted by residential development. Fecal coliforms, heavy metals, total suspended sediment, and nutrients are at or near the highest levels measured in the entire planning area.
- Lakota Creek, Joes Creek, and tributary 0390 bring sediment into Dumas Bay. Any future flow increases (particularly as predicted for Joes Creek) will accelerate this influx because of the highly erodable nature of their canyons' walls and beds.

REFERENCES

#### REFERENCES

# GEOLOGY, GROUNDWATER, AND EROSION AND DEPOSITION

- Applied Geotechnology, 1988, Unpublished report on the geology of the Midway Landfill.
- Armstrong, J. E., Crandell, D. R., Easterbrook, D. J., and Noble, J. B., 1965, Late Pleistocene stratigraphy and chronology in southwestern British Columbia and northwestern Washington: Geological Society of America Bulletin, v. 76, p. 321-330.
- Booth, D. B., 1989a, Geology: section in King County Surface Water Management Division, Soos Creek Basin Plan and Draft Environmental Impact Statement: Seattle, p. 46-51.
- -----1989b, Erosion, transport, and deposition of sediment: section in King County Surface Water Management Division, Soos Creek Basin Plan and Draft Environmental Impact Statement: Seattle, p. 51-58.
- -----1990a, Surficial geology of the Skykomish and Snoqualmie Rivers area, Snohomish and King Counties, Washington: U. S. Geological Survey Miscellaneous Investigations Map I-1745, scale 1:50,000.
- -----1990b, Stream-channel erosion and deposition: section in King County Surface Water Management Division, Draft Bear Creek Basin Plan: Seattle, p. 83-89.
- -----in press a, Geologic map of Vashon and Maury Islands, King County, Washington: U. S. Geological Survey Miscellaneous Field Investigations Map, scale 1:24,000.
- -----in press b, Stream-channel incision following drainage-basin urbanization: Water Resources Bulletin.
- Bretz, J H., 1913, Glaciation of the Puget Sound region: Washington Geological Survey Bulletin no. 8, 244 p.
- Crandell, D. R., Mullineaux, D. R., and Waldron, H. H., 1958, Pleistocene sequence in the southeastern part of the Puget Sound lowland, Washington: American Journal of Science, v. 256, p. 384-397.
- Department of Ecology, 1979, Coastal Zone Atlas, Volume 6 King County: Olympia, State of Washington, scale 1:24,000.
- Dunne, T., and Leopold, L. B., 1978, Water in environmental planning: New York, W. H. Freeman and Co., 818 p.
- Easterbrook, D. J., 1986, Stratigraphy and chronology of Quaternary deposits of the Puget Lowland and Olympic Mountains of Washington and the Cascade Mountains of Washington and Oregon: Quaternary Science Reviews, v. 5, p. 145-159.

## GEOLOGY, GROUNDWATER, AND EROSION AND DEPOSITION (continued)

- Easterbrook, D. J., Briggs, N. D., Westgate, J. A., and Gorton, M. P., 1981, Age of the Salmon Springs glaciation in Washington: Geology, v. 9, p. 87-93.
- Easterbrook, D. J., Crandell, D. R., and Leopold, E. B., 1967, Pre-Olympia Pleistocene stratigraphy and chronology in the central Puget Lowland, Washington: Geological Society of America Bulletin, v. 78, p. 13-20.
- King County, 1987, Basin Reconnaissance Reports (3 volumes): Seattle, King County Natural resources and Parks Division and Surface Water Management Division.
- Lea. P. D., 1984, Pleistocene glaciation at the southern margin of the Puget lobe, western Washington: Seattle, University of Washington, Department of Geological Sciences, M.S. thesis, 96 p.
- Leopold, L. B., 1973, River channel changes with time: an example: Geological Society of America Bulletin, v. 84, p. 1845-1860.
- Leopold, L. B., and Maddock, T., 1953, The hydraulic geometry of stream channels and some physiographic implications: U. S. Geological Survey Professional Paper 282-B.
- Mullineaux, D. R. 1970, Geology of the Renton, Auburn, and Black Diamond quadrangles, King County, Washington: U. S. Geological Survey Professional Paper 672, 92 p.
- Olmstead, T. L., 1969, Geotechnical aspects and engineering properties of glacial till in the Puget Lowland, Washington: in Proceedings, 7th Annual Engineering Geology and Soils Engineering Symposium,, Moscow, Idaho, p. 223-233.
- Shipman, H. 1990, Vertical land movement in coastal Washington: Washington Geologic Newsletter, v. 18, p. 26-33.
- South King County Ground Water Advisory Committee (SKCGWAC), 1989, Grant No. 1 Background Data Collection and Management Issues: Washington State Department of Ecology, 2 volumes.
- Thorson, R. M., 1980, Ice sheet glaciation of the Puget Lowland, Washington, during the Vashon stade: Quaternary Research, v. 13, p. 303-321.
- Waldron, H. H., 1961, Geology of the Poverty Bay Quadrangle: U. S. Geological Survey Map GQ-158, scale 1:24,000.
- Waldron, H. H., 1962, Geology of the Des Moines Quadrangle: U. S. Geological Survey Map GQ-159, scale 1:24,000.
- Westgate, J. A., Easterbrook, D. J., Naeser, N. D., and Carson, R. J., 1987, Lake Tapps tephra: an early Pleistocene stratigraphic marker in the Puget Lowland, Washington: Quaternary Research, v. 28, p. 340-355.

- GEOLOGY, GROUNDWATER, AND EROSION AND DEPOSITION (continued)
- Wolman, M. G., 1967, A cycle of sedimentation and erosion in urban river channels: Geographiska Annaler, v. 49A, p. 385-395.
- Wolman, M. G., and Miller, J. P., 1960, Magnitude and frequency of forces in geomorphic processes: Journal of Geology, v. 68, p. 54-74.

#### **HYDROLOGY**

- Barker, B., 1990. Draft Hylebos Creek Calibration Report: Unpublished Tech.
  Report, King County Surface Water Management Division, Seattle, Washington.
- Dinicola, R.S., 1989, Characterization and simulation of rainfall-runoff relations for headwater basins in western King and Snohomish Counties, Washington State: U.S. Geological Survey, Water-Resources Investigations Report.
- King County, 1989. Surface Water Design Manual, Seattle: King County Surface Water Management Division.
- Kite, G.W., 1988. Frequency and Risk Analysis in Hydrology, Colorado: Water Resources Publications, 115 p.
- U.S. Environmental Protection Agency, 1984. Hydrological Simulation Program Fortran User's Manual, Athens, Georgia: Environmental Research Laboratory.
- U.S. Water Resources Council, 1977. Guidelines for Determining Flood Flow Frequency, Bulletin 17A, Washington, D.C.

#### FLOODING

- American Society of Civil Engineers and the Water Pollution Control Federation,
  "Design and Construction of Sanitary and Storm Sewers," ASCE-Manuals and
  Reports on Engineering Practice No. 37 and WPCF Manual of Practice No. 9, 1969.
- Federal Emergency Management Agency, Federal Insurance Administration, Washington, D.C. "Flood Insurance Study for King County," 1989.
- Federal Emergency Management Agency, Federal Insurance Administration, Washington, D.C. "Flood Insurance Study for Pierce County," 1987.
- Federal Emergency Management Agency, Federal Insurance Administration, Washington, D.C. "Questions and Answers on the National Flood Insurance Program." Federal Insurance Administration, FIA 2, 1987.
- Federal Emergency Management Agency, Federal Insurance Administration, Washington, D.C. "Flood Insurance Study Guidelines for Study Contractors", Federal Insurance Administration, 1985.
- Federal Emergency Management Agency, Federal Insurance Administration, Washington, D.C. "Flood Insurance Study for the Town of Milton, Washington, King and Pierce Counties," 1981.

## FLOODING (continued)

- King County, "Adopted Capital Improvement Program Resource Book 89-94," 1989.
- King County Basin Reconnaissance Program, "Reconnaissance Report No. 8, Lower Puget Sound," 1987.
- King County Basin Reconnaissance Program, "Reconnaissance Report No. 3, Hylebos Creek Basin." 1986.
- King County Department of Public Works, "Surface Water Design Manual," Surface Water Management Division, 1990.
- King County Department of Public Works, "Pacific Highway South Drainage Study, Federal Way, Washington," Hydraulics Division, 1979.
- Pierce County, "Draft Stormwater Master Plan for the Hylebos Creek Basin," in preparation by James Montgomery and Associates, 1990.
- Pierce County, "Hylebos Basin Drainage Plan, Part A-1, Engineering Study for the Hylebos Flood Control Zone District," 1974.

#### WATER QUALITY

- Bannerman, R., 21 June 1990. Personal Communication (phone by Mr. Robert Storer, King County SWM, Seattle, WA). Wisconsin DNR, Madison, WI.
- Buckley, J., 19 June 1990. Personal Communication (phone by Mr. Robert Storer, King County SWM, Seattle, WA), Metro Environmental Laboratory, Seattle, WA.
- City of Kent. 1990. City of Kent Water Quality Study. City of Kent Public Works Department, Kent, WA. Water quality data results obtained since 1986 for site number 11 Smith Creek (South 251st Street and 16th Avenue South). Received by King County Surface Water Management Division on January 5, 1990.
- City of Seattle Engineering Department. 1988-1990. Water Quality Sample Results Sheets. Laucks Testing Laboratories, Inc. Longfellow and Piper Creeks. Delivered by Jennie Goldberg (Seattle Engineering Department to Bob Storer (King County Surface Water Management Division on March 12, 1990.
- Culp, Wesner, Culp Consulting Engineers and Ott Water Engineers. 1987. Technical memorandum: Appendix to final plan for combined sewer overflow control. Prepared for City of Everett Public Works Department, Everett, WA, p. A-21.
- Gavlin, D.V., and R.K. Moore. 1982. Toxicants in urban runoff. Metro Toxicant Program Report No. 2. Municipality of Metropolitan Seattle, Seattle, WA. 160 pp.
- Getz, L.L., A.W. Haney, R.W. Larimore, J.W. McNurney, H.V. Leland, P.W. Price, G.L. Rolfe, R.L. Wortman, J.L. Hudson, R.L. Solomon, and K.A. Reinhold, "Transport and Distribution in a Watershed Ecosytem," in Lead in the <a href="Environment">Environment</a>, R. Boggess, Ed., National Science Foundation, Washington, D.C., pp. 105-134 (1975).

## WATER QUALITY (continued)

- Gupta, M.K. and N.P. Kobriger, "Sources and Migration of Highway Runoff Pollutants," Envirex, Inc., Milwaukee (1980).
- Herrera Environmental Consultants. 1989. Water Resources Evaluation of the Proposed Regency Woods Neighborhood Center. Seattle, WA. Prepared for Venture Partners, Inc. 30pp. + appendix.
- Hopke, P.K., R.E. Lamb, and D.F.S. Natusch, 1990. "Multielemental Characteri-zation of Urban Roadway Dust." Environ. Sci. Technol., 14, 164.
- Kerri, K.D., M. Baad, E.C. Shirley, R.B. Howell, E. Torguson, and G. Winters, 1976. "Water Quality Manual, Vol. V: Chemical Bacteriological, and Ecosystem Analysis of Water from Highway Sources for Environmental Impact Assessments." Federal Highway Administration, Washington, D.C.
- Merrill, S., 1989. Analysis of Stormwater Monitoring Data for Time Trends and Land Use Differences Memo from Brown and Caldwell to Seattle Drainage and Wastewater Utility.
- Municipality of Metropolitan Seattle. 1988. Status of Water Quality in Small Lakes. Seattle-King County Region. 1988 Survey. Water Resources Section. Water Pollution Control Department. Publication 168. Municipality of Metropolitan Seattle. Seattle, WA.
- Municipality of Metropolitan Seattle. 1989a. Quality of Local lakes and Streams 1987-1988 Status Report. Water Resources Section. Water Pollution Control Department. Publication 168. Municipality of Metropolitan Seattle. Seattle, WA. 252 pp. + app.
- Municipality of Metropolitan Seattle. 1990. Results of Toxicity Tests on Stormwater Tested by Jim Buckley and Gary Yoshida, Metro Environmental Laboratory. 8 pp. Sent to Robert Storer, King County Surface Water Management Division, received on 6/20/90.
- Novotny, V. and G. Chesters, 1981. <u>Handbook of Nonpoint Pollution, Sources and Management</u>. New York, N.Y. Van Nostrand Reinhold Company, 322 pp.
- Portele, G.J., B.W. Mar, R.R. Horner, and E.B. Welch, "Effects of Seattle Area Highway Stormwater Runoff on Aquatic Biota,". January 1982. Report No. 11. A report prepared for the Washington State Department of Transportation Highway Runoff Water Quality Research Project. Department of Civil Engineering Environmental Engineering and Science Program. University of Washington, Seattle, WA. 33 p.
- PTI Environmental Services. 1988. Commencement Bay Nearshore/Tideflats
  Integrated Action Plan. Public Review Draft. Prepared for Washington
  Department of Ecology. PTI Environmental Services, Bellevue, WA. 101 pp. +
  appendix.
- Resource Planning Associates. 1985. Nonpoint Pollution in the Federal Way Community. Volume 2 Technical Analysis. Prepared for Lakehaven Sewer District. 50 pp. + appendices.

## WATER QUALITY (continued)

- Seattle-King County Department of Public Health. 1989. Memorandum from Pat Murphy, Southwest Public Health Center to Bob Storer, King County Surface Water Management Division. Included Thomas Brothers Map showing locations at which septic system repairs and overflows were reported in 1987. Seattle, WA.
- Scanlon, P.F., "A study of Lead, Cadmium, Nickel, and Zinc levels in Soil, Vegetation, Invertebrates and Mammals Associated with Highways of Different Traffic Densities," Report to U.S. Department of Transportation by Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg (1977).
- South King County Ground Water Advisory Committee. 1989. South King County Ground Water Management Plan. Grant Number 1. Background Data Collection and Management Issues. Volume 1. Prepared by South King County Ground Water Advisory Committee, Economic and Engineering Services, Inc., Hart-Crowser, Inc., Pacific Groundwater Group, and Robinson & Noble, Inc.
- Sullivan, R.H., et al. 1977. Nationwide Evaluation of CSO & Urban Stormwater Discharge. Vol.: Executive Summary EPA 600/2-77-064a.
- Tetra Tech. 1986. Recommended protocols for measuring selected environmental variables in Puget Sound. Final Report. Prepared for the U.S. Environmental Protection Agency and U.S. Army Corps of Engineers, Seattle, WA. Tetra Tech, Inc., Bellevue, WA.
- Tetra Tech. 1987. Commencement Bay Nearshore/Tideflats Feasibility
  Study: source evaluation refinement. Final Report. Prepared for
  Washington State Department of Ecology, Olympia, WA and U.S.
  Environmental Protection Agency, Region X, Seattle, WA. Tetra Tech,
  Inc., Bellevue, WA. 244 pp. + appendix.
- Tetra Tech. 1988. Elliott Bay revised action program: a storm drain monitoring approach. Final Report. Prepared for U.S. Environmental Protection Agency. Region X, Seattle, WA. Tetra Tech, Inc. Bellevue, WA. 100 pp. + appendices.
- U.S. Environmental Protection Agency. 1986. Quality criteria for water. U.S. Environmental Protection Agency, Office of Water Regulations and Standards. Washington, D.C.
- U.S. Environmental Protection Agency. 1987. Nationwide Urban Runoff Program (NURP). Summary Data Report for Bellevue, WA. Illinois State Water Survey (ISWS) Contract Report 410-2. Champaign, Illinois. 28 pp.
- U.S. Geological Survey. 1987. Water Quality in the Lower Puyallup River Valley and Adjacent Uplands, Pierce County, Washington.
  Water-Resources Investigations Report 86-4154. Prepared in cooperation with the Puyallup Tribe of Indians. U.S. Geological Survey, Tacoma, WA. 199 pp.

## WATER QUALITY (continued)

1

- Wang, T.Z., D.E. Spyridakis, B.W. Mar, and R.R. Horner, 1982. "Transport, Deposition and Control of Heavy Metals in Highway Runoff." A report prepared for the Washington State Department of Transportation Highway Runoff Water Quality Research Project. Report No. 10. Department of Civil Engineering, University of Washington, Seattle, WA. 33 pp.
- Washington State Department of Ecology. 1985. Metals Concentrations in Water, Sediment, and Fish Tissue Samples from Hylebos Creek Drainage, August 1983-September 1984. Completion Report on Water Quality Investigations Section Project 2. Memorandum to Jim Krull from Art Johnson and Dale Norton, Water Quality Investigations Section. Washington State Department of Ecology. Olympia, Washington.
- Washington State Department of Health. 1989. State Board of Health Drinking Water Regulations. Revised September 1989. Department of Health, Olympia, WA. 65 pp.
- Washington State Department of Ecology, 1988. Water quality standards for surface waters of the state of Washington. Chapter 173-201 WAC. 13 pp.
- Wisconsin DNR, 1990. Summary of Runoff Sample Toxicity Testing.
  Correspondence/Memorandum gaxed to Mr. Robert Storer, King County SWM,
  Seattle, WA) from Mr. Roger Bannerman, WI DNR, Madison, WI. June 21, 1990,
  2 pp.

#### **HABITAT**

- Brown, E.R. (1985). Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington. Portland: U.S. Dept. of Agriculture, U.S. Forest Service Pacific Northwest Region, Publication #R6-F&WL/192/1985.
- Canning, D.J., C.T. Bauer, B.B. Bunning, C. Jacobs, M.L. Mills, and J. Weber, 1990, Global Climate change and ozone depletion: the state of the knowledge for Washington State. Olympia, WA: Washington Dept. of Ecology, 65 pp.
- Dinicola, R.S., 1989, Characterization and simulation of rainfall-runoff relations for headwater basins in western King and Snohomish Counties, Washington State: U.S. Geological Survey Water-Resources Investigations Report.
- Gonor, J.J., J. R. Sedell, and P.A. Benner (1988) What we know about large trees in estuaries, in the sea, and on coastal beaches. In: Maser, C., R.F. Tarrant, J.M. Trappe, and J.F. Franklin, eds. From the Forest to the Sea: A Story of Fallen Trees. Portland, Oregon: U.S. Forest Service General Technical Report PNW-GTR-229, 1988. pp. 83-112.
- Hall, F.C. (1988) Characterization of riparian systems. In: Raedeke, R.J., ed., Streamside Management: Riparian Wildlife and Forestry Interactions. Seattle: University of Washington Institute of Forest Resources, Contribution No. 59.

#### HABITAT (continued)

- King County Planning Division, King County Wetlands Inventory Notebook, vol. 3. Seattle: King County Planning Division, 1983.
- Leopold, L.B. (1971) The hydrologic effects of urban land use. In: Detwyler, T.R., ed., Man's Impact on the Environment. New York: McGraw-Hill, Inc., pp. 205-224.
- Meehan, W.R., F.J. Swanson, and J.R. Sedell (1977). Influences of riparian vegetation on aquatic ecosystems with particular reference to salmonid fishes and their food supply. In: Symposium on the Importance, Preservation, and Management of the Riparian Habitat, July 9, 1977, Tucson, Ariz. pp.
- Meisner, J.D., J.S. Rosenfeld, and H.A. Regier (1988). The role of groundwater in the impact of climate warming on stream salmonines. Fisheries 13: 2-8.
- Mundie, J.H., 1969. "Ecological Implications of the Diet of Juvenile Coho in Streams." In Symposium on Salmon and Trout in Streams, ed. T.G. Northcote, 135-152. Vancouver: University of British Columbia, MacMillan Lectures in Fisheries.
- Mundie, J.H. Elements of stream ecology. Nanaimo, B.C.: Canada Dept. of the Environment, Fisheries and Marine Service, Pacific Biological station. No date. 4 pages.
- Reeves, G.H., F.H. Everest, and T.E. Nickelson (1989). Identification of Physical Habitats Limiting the Production of Coho Salmon in Western Oregon and Washington. U.S. Forest Service General Technical Report #PNW-GTR-245, 18 pages.
- Ridge-Cooney, V. (1988) Hylebos/Lower Puget Sound Drainage Basin Habitat Report. Seattle: Municipality of Metropolitan Seattle (METRO), 23 pages.
- Sedell, J.R., P.A. Bisson, F.J. Swanson, and S.V. Gregory (1988) What we known about large trees that fall in streams and rivers. In: Maser, C., R.F. Tarrant, J.M. Trappe, and J.F. Franklin, eds. From the Forest to the Sea: A Story of Fallen Trees. Portland, Oregon: U.S. Forest Service General Technical Report PNW-GTR-229, pp. 47-81.
- Whipple, W., Jr., J.M. DiLouie, and T. Pytlar, Jr. 1981. Erosional potential of streams in urbanizing areas. Water Res. Bull. 17:36-45.

#### OTHER

- City of Des Moines; 1981-1990 Greater Des Moines Comprehensive Plan; City of Des Moines, Washington; 1981; p. 52
- King County Planning Division; Federal Way Community Plan and Area Zoning; King County, Washington; 1986; p. 134

# OTHER (continued)

- King County Planning Division, 1989 Annual Growth Report, King County, Washington, 1989, p.85
- Pierce County, 1964, Pierce County Generalized Comprehensive Plan, Tacoma, WA, pp. 24.
- Tiffany, Chris; Gary Minton; Rachel Friedman-Thomas; "Draft Erosion and Sedimentation Control: An Evaluation of Implementation of BMPs on Construction Sites in King County, Washington, January 1988 April 1989"; King County, Washington; 1990.